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MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

Vol. LXI. No. 1. November 1900.

SUPPLEMENTARY CATALOGUE OF THE LIBRARY.

Fellows are informed that the Supplementary Catalogue, containing titles of works added to the Library from June 1884 to June 1898, is published, and may be had on application to the Assistant Secretary. Price 1*s.* to Fellows and 2*s.* to the public; postage 3*d.*

INVITATION OF LADIES TO THE ORDINARY MEETINGS OF THE SOCIETY.

The attention of Fellows is called to the fact that ladies are only admitted to the Ordinary Meetings of the Society by special invitation of the President, sanctioned by the Council. The invitations are issued at the commencement of each Session.

MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY,

CONTAINING

PAPERS, ABSTRACTS OF PAPERS, AND

REPORTS OF THE PROCEEDINGS

OF THE SOCIETY

FROM NOVEMBER 1900 *TO NOVEMBER* 1901.

VOL. LXI.

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MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

Vol. LXI. November 9, 1900. No. 1

E. B. Knobel, Esq., President, in the Chair.

A. H. Baker, B.A., Head Master, Basnett Road Board School, Lavender Hill, S.W.;
William Henry Colegrave, Master Mariner, Little Tew, Enstone, Oxford; and
Guy François Comte Meredyth de Miremont, Orleans Club, St. James's, S.W., and Littlecot, Worthing, Sussex.

were balloted for and duly elected Fellows of the Society.

The following candidates were proposed for election as Fellows of the Society, the names of the proposers from personal knowledge being appended:—

Charles Anthony, jun., M.I.C.E., Casilla 1045, Buenos Aires, Argentine Republic (proposed by Sir R. S. Ball);
Henry Osmund Barnard, Superintendent, Trigonometrical Survey, Survey Department, Ceylon (proposed by Capt. P. B. Molesworth);
Archibald Young Gipps Campbell, Civil Service of India (proposed by Sir R. S. Ball);
Charles Davidson, Established Computer, Royal Observatory, Greenwich, 41 Park Street, Greenwich, S.E. (proposed by W. H. M. Christie);
Frank C. Dumat, Advocate, Johannesburg, South Africa (proposed by E. Nevill);
Ambrose T. Flagg, M.A., Head Master, Navigation School, Chapel House, Westoe, South Shields (proposed by Thomas Lewis);

Walter Heath, M.A., Redcott, Cobham, Surrey (proposed by J. W. L. Glaisher);

John Charles William Herschel, B.A. Oxon, St. John's College, Cambridge, and Lawn Upton, Littlemore, near Oxford (proposed by Sir R. S. Ball);

Capt. Joseph W. Martyr, s.s. "Montrose," 1 The Glen, South Road, Forest Hill, S.E. (proposed by Campbell Hepworth);

Alfred Ernest Moore, B.A., B.Sc. Lond., Lecturer in Mathematics and Physical Science, St. John's College, Battersea, S.W. (proposed by A. Fowler);

John Netherclift Jutsum, Teacher of Navigation and Nautical Astronomy, Cardiff Nautical Academy, 47 St. Mary Street, Cardiff, S. Wales (proposed by Arthur Mee);

Thomas Marginson Nightingale, B.Sc., 375 Bridgeman Street, Bolton, Lancashire (proposed by A. Fowler); and

Richard Welford, Thornfield Villa, Gosforth, near Newcastle-on-Tyne (proposed by Cuthbert Hutchinson).

One hundred and eighty-eight presents were announced as having been received since the last meeting, including, amongst others :—

J. C. Adams, Scientific Papers, vol. ii., presented by the Adams Memorial Committee; Ch. André, Traité d'astronomie stellaire, 2me partie, presented by the author; Batavia, Natural History Society, Solar eclipse of 1901; information for observing parties, &c., presented by A. M. W. Downing; Groningen Astronomical Laboratory, publications Nos. 1–3, presented by the Laboratory; Leipzig, Astronomische Gesellschaft, Catalog der Sterne, Zone $+10°$ bis $+15°$ (Leipzig), presented by the Society; Lowell Observatory Annals, vol. ii., presented by Percival Lowell; Madrid Observatory, Observaciones del eclipse total 1900 in Plasencia, presented by the Observatory; E. W. Maunder, The Royal Observatory, Greenwich, presented by the publishers; Princeton University, Report of the eclipse expedition, 1900, presented by C. A. Young; Washington, American Ephemeris Papers, vol. v., pts. 1, 2; vol. viii., pt. 1 (Newcomb, Perturbative Function, Inequalities of long period, Precessional Constant), presented by the Ephemeris Office. Carte photographique du ciel, 70 charts, from photographs taken at the Observatories of Algiers, Paris, Toulouse, and San Fernando, presented by the Paris and San Fernando Observatories; Collection of astronomical drawings (Moon and planets) by the late N. E. Green, presented by Miss Green; Photographs of the total solar eclipse, 1900 May 28, presented by C. Burckhalter; Photographs of the Sun and of the solar eclipse, 1900 May 28 (partial

phase), presented by G. J. Newbegin; Photographs of instruments for eclipse observations and enlarged photograph of the transit of *Venus*, 1882, presented by D. P. Todd; Portrait of the late Professor J. E. Keeler, presented by the Lick Observatory; Small equatorially mounted telescope, formerly belonging to the late Mr. B. T. Moore, presented by Miss Moore.

Mean Areas and Heliographic Latitudes of Sun-spots in the year 1899, deduced from Photographs taken at the Royal Observatory, Greenwich, at Dehra Dûn (India), and in Mauritius.

(*Communicated by the Astronomer Royal.*)

The results here given are in continuation of those printed in the *Monthly Notices*, vol. lx. p. 157, and are deduced from the measurements of solar photographs taken at the Royal Observatory, Greenwich; at Dehra Dûn, India; and at the Royal Alfred Observatory, Mauritius.

Table I. gives the mean daily areas of umbræ, whole spots, and faculæ for each synodic rotation of the Sun in 1899; and Table II. gives the same particulars for the entire year 1899 and the ten preceding years, for the sake of comparison. The areas are given in two forms: first, projected areas—that is to say, as seen and measured on the photographs, these being expressed in millionths of the Sun's apparent disc; and next, areas as corrected for foreshortening, the areas in this case being expressed in millionths of the Sun's visible hemisphere.

Table III. exhibits for each rotation in 1899 the mean daily area of whole spots, the mean heliographic latitude of the spotted area, and the mean distance from the equator of all spots; and Table IV. gives the same information for the year as a whole similar results from 1889 to 1898 being added, as in the case of Table II. Tables II. and IV. are thus in continuation of the similar tables for the years 1874 to 1888, on pp. 381 and 382 of vol. xlix. of the *Monthly Notices*.

The rotations in Table I. and Table III. are numbered in continuation of Carrington's series (*Observations of Solar Spots made at Redhill*, by R. C. Carrington, F.R.S.), No. 1 being the rotation commencing 1853 November 9. The assumed prime meridian is that which passed through the ascending node at mean noon on 1854 January 1, and the assumed period of the Sun's sidereal rotation is 25·38 days. The dates of the commencement of the rotations are given in Greenwich civil time, reckoning from mean midnight.

TABLE I.

No. of Rotation.	Date of Commencement of each Rotation.	No. of Days on which Photographs were taken.	Mean of Daily Areas. Projected Umbræ.	Projected Whole Spots.	Projected Faculæ.	Corrected for Foreshortening. Umbræ.	Corrected for Foreshortening. Whole Spots.	Corrected for Foreshortening. Faculæ.
	d							
605	1898 Dec. 18·20	27	44	271	399	28	182	436
606	1899 Jan. 14·53	27	28	154	402	19	108	424
607	Feb. 10·87	27	7·0	38	218	7·0	36	248
608	Mar. 10·20	28	82	485	441	55	336	474
609	Apr. 6·50	27	30	159	344	22	116	411
610	May 3·76	27	9·6	61	211	7·1	44	259
611	May 30·97	27	29	173	410	22	137	487
612	June 27·17	27	73	448	439	49	301	488
613	July 24·37	27	5·0	21	345	2·7	15	365
614	Aug. 20·60	27	0	3·0	161	0	2·1	177
615	Sept. 16·86	28	9·7	54	160	5·6	30	185
616	Oct. 14·14	27	20	129	152	13	81	198
617	Nov. 10·44	28	13	67	233	8·5	48	279
618	Dec. 7·76	27	9·9	72	263	6·9	51	277

TABLE II.

Year.	No. of Days on which Photographs were taken.	Mean of Daily Areas. Projected. Umbræ.	Projected. Whole Spots.	Projected. Faculæ.	Corrected for Foreshortening. Umbræ.	Corrected for Foreshortening. Whole Spots.	Corrected for Foreshortening. Faculæ.
1889	360	17·9	103	107	13·1	78·0	131
1890	361	21·3	133	273	15·5	99·4	304
1891	363	120	745	1322	86·2	569	1412
1892	362	255	1596	3230	186	1214	3270
1893	362	327	1983	2287	234	1464	2404
1894	364	317	1728	1666	231	1282	1877
1895	364	237	1330	2059	169	974	2278
1896	364	127	745	1243	90	543	1410
1897	364	122	695	977	83	514	1149
1898	363	93	532	767	64	375	891
1899	364	27	159	297	18	111	337

TABLE III.

No. of Rotation.	Date of Commencement of each Rotation.	No. of Days on which Photographs were taken.	Spots North of the Equator. Mean of Daily Areas.	Spots North of the Equator. Mean Heliographic Latitude.	Spots South of the Equator. Mean of Daily Areas.	Spots South of the Equator. Mean Heliographic Latitude.	Mean Heliographic Latitude of Entire Spotted Area.	Mean Distance from Equator of all Spots.
	d			°		°	°	°
605	1898 Dec. 18·20	27	4·5	8·45	178	11·68	−11·17	11·60
606	1899 Jan. 14·53	27	0·1	7·95	108	11·05	−11·04	11·05
607	Feb. 10·87	27	0·0	...	36	5·39	− 5·39	5·39
608	Mar. 10·20	28	5·5	10·76	331	10·63	− 9·67	10·03
609	Apr. 6·50	27	11	9·53	105	10·82	− 8·85	10·70
610	May 3·76	27	0·0	...	44	11·84	−11·84	11·84
611	May 30·97	27	97	5·95	41	12·90	+ 0·39	8·00
612	June 27·17	27	150	5·93	152	9·99	− 2·09	7·98
613	July 24·37	27	0·0	...	15	11·58	−11·58	11·58
614	Aug. 20·50	27	0·4	2·95	17	10·43	− 7·94	9·03
615	Sept. 16·36	28	15	4·18	15	12·20	− 4·14	8·25
616	Oct. 14·14	27	0·1	6·95	81	9·97	− 9·94	9·96
617	Nov. 10·44	28	4·1	3·96	44	7·54	− 6·55	7·23
618	Dec. 7·76	27	29	7·16	22	11·61	− 0·97	9·09

TABLE IV.

Year.	No. of Days on which Photographs were taken.	Spots North of the Equator. Mean of Daily Areas.	Spots North of the Equator. Mean Heliographic Latitude.	Spots South of the Equator. Mean of Daily Areas.	Spots South of the Equator. Mean Heliographic Latitude.	Mean Heliographic Latitude of Entire Spotted Area.	Mean Distance from Equator of all Spots.
			°		°	°	°
1889	360	5·0	7·26	73·0	11·90	−10·68	11·61
1890	361	53·1	22·20	46·3	21·75	+ 1·73	21·99
1891	363	401	20·49	169	19·91	+ 8·52	20·31
1892	362	607	15·09	607	21·69	− 3·29	18·39
1893	360	517	14·91	941	14·26	− 3·93	14·49
1894	364	543	12·31	739	15·56	− 3·75	14·18
1895	364	565	14·26	409	12·54	+ 3·01	13·54
1896	364	203	13·60	340	14·77	− 4·15	14·33
1897	364	196	8·32	318	7·73	− 1·62	7·96
1898	363	110	9·82	266	10·77	− 4·75	10·49
1899	364	23	6·18	88	10·43	− 6·95	9·54

The principal features of the record for 1899 are :—

(1) The decline in area of umbræ, whole spots, and faculæ has gone on with great rapidity; the decrease in mean daily spotted area amounting to 70 per cent. for 1899, as compared with 1898, and to 78 per cent. as compared with 1897.

(2) The decrease in the area of the umbræ has been in almost exactly the same proportion as for the whole spots—72 per cent. as compared with 1898, 80 per cent. as compared with 1897.

(3) The decrease in the area of the faculæ has been almost as great—62 per cent. as compared with 1898, 71 per cent. as compared with 1897.

(4) The northern hemisphere has been much the least active, giving only one-fifth of the total mean daily spotted area.

(5) The rate of decline in the two hemispheres has not been very different, but has been greatest in the northern; the decrease, as compared with 1898, is 79 per cent. for the northern hemisphere, and 67 for the southern.

(6) The two chief outbreaks of the year occurred in March and June respectively, but were both very far inferior to the great group of September 1898; indeed, neither of them would have been at all noticeable at the period of maximum. The first of these groups was first seen near the east limb on March 15, and disappeared at the west limb on March 27. It was seen only during the one rotation. The other group was first seen on the east limb on June 23, having formed on the further hemisphere. It consisted at first chiefly of one very large regular spot, and like the March group was seen only during one passage.

(7) The distribution of the spots in latitude in 1899 has been marked by a slight approach towards the equator, the mean distance being $9^{\circ}\cdot54$ as compared with $10^{\circ}\cdot49$ in 1898. This latitude is distinctly higher than that for the year 1887 in the last cycle, but is almost exactly the same as for 1877 in the preceding cycle.

(8) The number of days without spots has very greatly increased, having risen to 123, as against 48 for 1898. The number of days without faculæ has increased even in a larger ratio, being 105, as against 11 in 1898.

(9) As compared with 1887, the mean daily spotted area is much smaller, being 111 as against 179; so that the decline towards the minimum would, so far as this element is concerned, seem to be further advanced in 1899 than in 1887. The number of days without spots also supports the same conclusion. The mean distance of the spots from the equator rather points to 1899 being further from the minimum than was 1887. On the whole, if the general progress of the present cycle follows the course of the last, the next minimum should fall sometime in the latter half of 1901.

Micrometric Measures of the Diameter of Neptune and distance and position-angle of the Satellite made with the 28-inch refractor at the Royal Observatory, Greenwich.

(*Communicated by the Astronomer Royal.*)

The following measures were made with the full aperture of the 28-inch refractor and a power of 670. No correction for irradiation has been applied to the measures of diameters.

The initials L., B., W. B. are those of Mr. Lewis, Mr. Bryant, and Mr. Bowyer respectively.

Micrometric Measures of the Diameter of Neptune.

Date.	Apparent Diameter. Equatorial.	Apparent Diameter. Polar.	No. of Measures.	Diameter reduced to mean distance, 30·05508. Equatorial.	Diameter reduced to mean distance, 30·05508. Polar.	Observer.
1896.	″	″		″	″	
Nov. 18	2·10	2·03	10, 10	2·02	1·96	L.
20	2·05	1·91	10, 10	1·98	1·83	„
1897.						
Dec. 17	2·03	2·10	10, 10	1·95	2·02	„
20	...	2·14	6	...	2·07	W.B.
22	2·34	...	10	2·25	...	B.
	2·38	2·27	10, 10	2·27	2·18	L.
24	2·20	2·64	8, 8	2·11	2·54	W.B.

Micrometric Measures of the Satellite of Neptune.

Date and Mean Time.		Sidereal Time.	No. of Measures.	Apparent Distance.	Distance reduced to mean distance of Neptune (30·05508).	Position-Angle.	Observer.
1896. d	h m s	h m s		″	″	° ′	
Nov. 18	12 38 9	4 32 20	8	15·94	15·35	...	L.
	12 33 12	4 27 22	4	...	...	264 9	„
30	11 38 32	4 19 52	10	17·35	16·68	...	„
	11 38 8	4 19 28	4	...	...	251 53	„
Dec. 7	11 7 56	4 16 47	6	13·17	12·95	...	„
	11 9 17	4 18 8	4	...	...	204 2	„
31	9 29 42	4 12 54	10	11·06	10·65	...	„
	9 18 56	4 2 6	4	...	...	167 30	„
1897							
Nov. 29	9 42 52	2 19 0	13	14·94	14·37	...	„
	9 38 48	2 14 55	4	...	...	275 8	„
Dec. 3	10 57 1	3 49 7	5	16·09	15·46	...	„
	10 50 49	3 42 53	4	...	...	58 55	„
17	10 5 20	3 53 29	10	16·74	16·09	...	„
	9 56 27	3 44 34	4	...	...	258 18	„

Date and Mean Time.			Sidereal Time.	No. of Measures.	Apparent Distance.	Distance reduced to mean distance of Neptune (30·05508).	Position-Angle.	Observer.
1897.	d	h m s	h m s		″	″	° ′	
Dec.	20	10 53 36	4 52 42	16	17·92	17·23	...	W.B.
		10 50 57	4 50 3	4	...	...	77 26	”
	22	9 24 30	3 31 16	10	11·82	11·36	...	B.
		9 24 15	3 31 0	8	...	...	309 10	”
		10 21 20	4 28 14	10	11·55	11·11	...	L.
		10 21 22	4 28 17	5	...	...	303 4	”
	23	9 56 5	4 6 51	10	17·28	16·62	...	”
		9 55 43	4 6 29	5	...	...	249 59	”
	24	10 11 17	4 26 3	20	13·29	12·78	...	W.B.
		10 6 34	4 21 19	4	...	...	207 21	”
	28	9 46 15	4 16 43	20	13·66	13·15	...	”
		9 47 3	4 17 33	4	...	...	292 57	”
1898. Jan.	10	9 38 22	5 0 4	10	16·17	15·61	...	L.
		9 30 12	4 51 53	4	...	...	240 16	”

Royal Observatory, Greenwich:
October 1900.

Corrections to the Armagh Catalogue for 1840.
By J. L. E. Dreyer, PhD.

Most of the corrections to the Armagh Catalogue given below are the results of an examination of the reductions of a number of stars made two years ago at the request of Professor Auwers. In addition to the ordinary arithmetical errors likely to occur in a vast amount of figure work, the Armagh star-places are not infrequently vitiated by errors for which the peculiar method of reduction adopted by Dr. Robinson is responsible. The right ascension of every star to be determined was taken from some catalogue (at first Piazzi or the A.S.C., later often the B.A.C.), brought up to the beginning of the year and reduced to apparent place, and this "assumed R.A." was then compared with the observed time of meridian transit. The result of this comparison was a clock error, and the difference between that and the clock error found by standard stars was adopted as the "correction to assumed R.A." of the star in question. Similarly in N.P.D. the comparison gave an "index error," the difference of which from the index error found by the nadir observation gave the "correction to assumed N.P.D." It is obvious that this roundabout way of reducing the observations gave abundant opportunities of

blundering. For instance, not a few errors were introduced by the computers, in the course of years, taking the assumed place of a star from different catalogues and then overlooking this when making up the final catalogue, so that the mean of the "corrections to assumed place" in some instances was applied to a star-place which was not that to which some of the individual corrections really corresponded.

In addition to the copious list of errata given at the end of the catalogue,* there is a further list at the end of the *Second Armagh Catalogue*, in which for No. 1035 read No. 1435, while the N.P.D. of the star is 31° 29′ 51″·87.

The following list contains all the corrigenda noticed since 1886:—

No. 540. On p. 67, the single results in P.D. should be:

$$\begin{array}{r} '' \\ -0{\cdot}90 \\ -1{\cdot}47 \\ +0{\cdot}33 \\ +0{\cdot}30\,; \end{array}$$

and the final N.P.D. is 82° 15′ 38″·29.

No. 576. On p. 71, the single results in R.A. should be:

$$\begin{array}{r} s \\ +0{\cdot}12 \\ -0{\cdot}18 \\ -0{\cdot}06 \\ +0{\cdot}57\,; \end{array}$$

and the final R.A. should be $2^h\ 31^m\ 9^s{\cdot}60$.

No. 585. The result in P.D. on 1844 December 2 should be +0″·78, and the final N.P.D. 41° 27′ 11″·16.

Nos. 1373, 1389. 36 *Camelop.* and *Radcliffe* 1661. The observer at the Mural Circle never saw more than one star. On 1840 March 5 and 1841 February 20 he certainly observed the preceding star, and on 1839 February 10, 1840 February 13, 1844 February 16, and 1851 January 2 he certainly observed the following one; but on the other nights it is impossible to say which he observed, as he did not give the minute of P.D., and the stars differ nearly 1′ in P.D. There seem to be no errors in the reductions.

No. 1945. ι *Cancri*. 1834 February 24, only *Procyon* and *Pollux* observed for time, and there must be some error in the observation of *Procyon*. The clock error taken from *Pollux* only

* It may seem superfluous to draw attention to this, but experience shows that astronomers frequently overlook lists of errata. Sir John Herschel, for instance, when preparing his *General Catalogue of Nebulæ*, seems to have taken no notice of the errata given in his own Cape Observations.

agrees perfectly with the rate of the clock from February 23 and 25. Adopting this, we get for the stars observed this evening :

		Correction to Assumed Place.	Final R.A. in Catalogue.
		s	s
1945	ι Cancri	+0·41	0·30
2406	χ Leonis	+0·34	45·67
2433	69 „	+0·05	34·03
2454	76 „	+0·45	42·15
2469	ι „	+0·54	34·73
2484	τ „	+0·20	42·37
2648	c Virg.	+0·56	13·52

No. 2457. δ *Crateris.* Confusion in the assumed places in N.P.D. The mean result is 103° 54′ 47″·54.

No. 2507. Approximate P.D.=19° 50′.

No. 2899. The first result in R.A. should be $+0^s\cdot05$; final mean, $13^h\ 27^m\ 38^s\cdot54$.

No. 3060. Minute of P.D. is 27′.

No. 324c. ν^2 *Boötis.* Always hurriedly observed in R.A. after 52 *Boötis.*

No. 4003. Observed after 55 *Draconis*; no estimate of N.P.D. given. According to Schröter, of Christiania (*A. N.* 3527), it is not on the parallel of 55 *Draconis.*

No. 4698. Seconds of N.P.D., 46″·69.

No. 4781. For single results, see p. 832.

No. 5003. Observation of 1838 November 11 (over one wire and through clouds) should be rejected. This makes seconds of R.A.=$58^s\cdot11$.

No. 5175. Single results in N.P.D. should be +2″·75 and +5″·30, and N.P.D.=67° 28′ 31″·51.

No. 5181. On p. 627, for 4″·76 read +10″·18. Seconds of P.D. are 6″·15.

On the Variable Velocity of α Persei. By H. F. Newall.

From measurements which have been made of photographs recently taken at the Cambridge Observatory, it appears that *α Persei* has a variable velocity in the line of sight.

Eleven photographs were secured during 1900 September and October with the large four-prism spectroscope that was used in the observations of *Capella.* The spectra are taken with a long camera, and the linear dispersion is 6 tenth-metres per millimetre. The spectra are measured with a Zeiss micrometer, which is so arranged that ten revolutions of the micrometer screw correspond to 1 millimetre ; thus one revolution of the micrometer corresponds to 0·6 tenth-metre, and there is not much

difficulty in setting the wires on the lines of the photographed spectra with such precision as to give the wave-length of the lines within one-hundredth of a tenth-metre. In terms of velocity, one revolution of the micrometer corresponds to about 40 kilometres per second.

The following table contains a statement of the results obtained from the above-mentioned photographs. Each spectrum has been measured in the manner described in a previous paper (*Monthly Notices*, vol. lx. p. 418). The values given for the velocity are means of two measurements made, one by myself, the other by my assistant, A. W. Goatcher. There is a systematic difference of about 2 km./sec. between our results; this requires further investigation, but does not affect the broad facts established by the work as a whole.

Velocity of a Persei in the Line of Sight.

Plate Number		Velocity Relative to Earth.	Correction for Earth's Orbital Velocity.	Velocity Relative to Sun.
F. 118	1900 Sept. 6·54	−20·9	+24·8	+3·9
F. 121	Sept. 11·58	−26·4	+24·2	−2·2
F. 123	Sept. 13·48	−24·3	+23·9	−0·4
F. 125	Sept. 17·52	−22·2	+23·3	+1·1
F. 126	Sept. 19·52	−21·1	+22·9	+1·8
F. 128	Sept. 21·50	−16·9	+22·5	+5·6
F. 130	Oct. 4·46	−16·0	+19·3	+3·3
F. 131	Oct. 10·44	−15·4	+17·5	+2·1
F. 132	Oct. 21·44	−10·5	+13·6	+3·1
F. 134	Oct. 26·39	− 4·2	+11·7	+7·5
F. 135	Oct. 27·41	−10·9	+11·3	+0·4

Three other photographs taken with half the linear dispersion were secured in 1899 October. They have been measured, with the following results :—

F. 23	1899 Oct. 5·46	−22·7	+18·9	−3·8
F. 26	Oct. 9·46	−15·5	+17·7	+2·2
F. 28	Oct. 10·44	−17·9	+17·4	−0·5

A preliminary discussion of the variable velocity leads me to alternative conclusions, between which it is not possible to decide until more material is collected. The conclusions are that *a Persei* may move either in an approximately circular orbit in a period of 4·20 days, or in an elliptical orbit of considerable eccentricity in a period of about 16·8 days.

The range of velocities observed at Cambridge is small, lying between −4 and +8 km./sec. The Potsdam observations in 1888 give a velocity of −10 km./sec. Professor Campbell's obser-

vations at the Lick Observatory are recorded in the *Astrophysical Journal*, vol. viii. p. 150 :—

1896 Nov. 11·8	...	...	...	−2·0
Nov. 12·8	...	...	...	−1·8
1897 Jan. 19·6	...	...	...	−3·5
1898 July 12·0	...	...	...	−2·1

Curiously enough, the dates of the latter observations are so related as not to give decisive evidence as to which of the suggested periods is most probable.

More material is required, and it should be gathered in photographs taken at short intervals. I beg to present this note in the hope that other observers may be able to secure observations whilst *a Persei* is in favourable position.

1900 *November* 8.

On the Disappearance from Photographic Films of Star-images and their Recovery by the aid of a Chemical Process. By Isaac Roberts, D.Sc., F.R.S.

On p. 15 of my second volume of photographs of *Stars, Star-Clusters and Nebulæ* I gave instances of the disappearance of the images of many faint stars from the films of negatives, which had been taken nine and a quarter and nine and one-fifth years respectively, between the dates when the images were counted. This statement was seen by Sir William Crookes, and he informed me that probably by the application of chemical reagents the images that had become invisible might be restored to view ; and further he generously offered to try the experiment if I would send him the negatives ; which offer, of course, I gladly accepted.

The two negatives referred to in my book were sent, and in a short time they were returned to me with the request that I should examine them and report if the experiment had succeeded. I thereupon recounted the star-images on the plates and found that every one of the missing images had been restored to view as distinctly, I think, as they were after the negatives were first developed ; the experiment therefore had succeeded perfectly.

Sir William Crookes readily placed at my disposal the formulæ of the reagents he had employed in the experiment, with permission to publish them, thus placing me, and all others who may be engaged in the work of photographing the stars and nebulæ, under obligation to him.

The following are the formulæ and processes employed by Sir William Crookes as they were given in his letter to me :—

"1. Soak the plate for three hours in distilled water.

"2. Prepare, in advance, two solutions, A and B.

Solution A.		Solution B.	
Pyrogallic acid . .	1 oz.	Sodium carbonate (crystals)	12 oz.
Sodium metabisulphite	1 oz.	Sodium sulphite . . .	4 oz.
Water	80 oz.	Water	80 oz.

"Mix equal parts of A and B, and allow the plate to soak in the mixture for ten minutes or a quarter of an hour, in the dark. Wash well.

"3. Transfer the washed plate to a solution of 3 oz. of sodium hyposulphite in 20 of water. Allow it to remain for half an hour, and then wash the plate in running water for three hours.

"4. Prepare a 'Clearing' solution according to the following formula :—

Alum	1 oz.
Citric acid	1 oz.
Ferrous sulphate . . .	3 oz.
Water	20 oz.

"Allow the plate to soak in this for ten minutes, and then remove and wash in running water for six hours.

"5. Prepare, in advance, two solutions, C and D.

Solution C.		Solution D.	
Ammonium sulphocyanide	100 gr.	Gold chloride . .	15 gr.
Water	10 oz.	Water	15 oz.

"For use take 1 oz. of each, and add 8 oz. of water. Soak the plate in this mixture for ten minutes, and at the end of the time remove and wash it in running water for half an hour. Transfer to a dish of distilled water, where it may remain for an hour. Finally drain on blotting paper and allow to dry.

"The separate solutions A, B, C, D will keep for an indefinite time, and the same may be said of the clearing solution, if kept tightly corked. But when mixed together they will not keep, so fresh mixtures should be made each time.

"I have given you the full process adopted on the plates you sent me, but I think some of them may be omitted with no disadvantage. For example, I should like to try if the soaking in hyposulphite may be dispensed with. I think it can, but I only tried leaving it out on the plates you sent that had not faded.

"I always found the great secret of preventing images from fading out was to wash them very well in running water. The clearing solution allows the time of washing to be a little shortened, but not much.

"The sulphocyanide and gold solution has the property of precipitating gold on the image, and rendering it of a blacker colour and diminishing the chance of fading. I should think

you would find it useful always to use the clearing solution and the sulphocyanide and gold solution in your usual process.

"(Signed) WILLIAM CROOKES."

1900 *July* 6.

On the near Approach of the Planet Eros to a Star (B.D. + 48°, 759). By F. A. Bellamy.

The planet *Eros* is under regular photographic observation at the University Observatory, Oxford, for determining the parallax.

The plan of work adopted is to get several exposures as soon after sunset and as soon before sunrise as possible. It may be of interest to give a summary of plates at present taken. Fifty sets of exposures, either evening or morning, have been secured with an aggregate of 205 exposures, varying from 10^m to 30^s; on ten occasions pairs of parallax plates have been obtained (evening and morning). Since October 31 the weather has been very unfavourable, and only two plates have been exposed. All images of *Eros* and all the stars in the A.G. Catalogues of Harvard and Bonn which come within the area of the plates have been measured, and many of the plate constants determined provisionally. On October 12 the sky was thickly overcast until $8\frac{1}{2}$ P.M. I came out of the Observatory a few minutes later and noticed a break in the clouds in the west, and decided to get the instrument ready in case a fine interval should come over; by 8·45 the sky was almost cloudless, and I secured 10 exposures on plates 1632 and 1633 within the next 50 minutes; 10 minutes later the sky was completely cloudy and remained so.

The chief point of interest in these two plates is the proximity of *Eros* to a star, since identified as B.D. + 48°, 759. From the first to the fifth exposures the angular distance decreased, the planet moving north and west, until at the sixth and seventh exposures the images of star and planet are confused (see diagram, p. 18). The following measures were made by myself, using one of the Astrographic Catalogue measuring instruments, the unit adopted being 1 réseau interval of 5′.

Plates 1632 *and* 1633 *Exposed* 1900 *Oct.* 12. *R.A.* $2^h\ 42^m + 49°$.

Exp.	Mag. Eros.	Mag. ✡	Eros x	✡ x	Eros − ✡.	Eros y.	✡ y.	Eros − ✡.	Oxford Sid. Time of Middle of Exposure. h m s
1	18	17	14·124	14·082	+ ·042	10·966	11·057	− ·091	22 6 12
2	15	15	·116	·077	+ ·039	·895	10·970	− ·075	11 22
3	20	20	·114	·080	+ ·034	·812	·874	− ·062	16 27
4	19	19	·106	·079	+ ·027	·731	·778	− ·047	21 46
5	16	17	·100	·075	+ ·025	·649	·679	− ·030	25 57
6	21?	22?	·062	·049	+ ·013	·939	·942	− ·003	36 12
7	18?	20?	·060	·050	+ ·010	·849	·838	+ ·011	41 2
8	16	19	·055	·046	+ ·009	·758	·733	+ ·025	45 27
9	14	18	·050	·047	+ ·003	·651	·619	+ ·032	49 2
10	10	13	14·046	14·042	+ ·004	10·562	10·516	+ ·046	22 52 42

The measures of the 6th and 7th exposures are not very satisfactory owing to the coalescent images.

The motion in x, between the 1st and 10th exposures, is ·038 in $46^{m}·5$ and in y ·137, being equivalent to ·00082 in x, and ·00295 in y for 1^{m}. If the epoch of nearest approach be adopted as $22^{h}\ 37^{m}\ 10^{s}$, the following results are obtained :—

Time of Exposure from Epoch. m	Planet's Motion.	Measured x.	Sum.	Planet's Motion.	Measured y.	Sum.
−31·0	−·025	+·042	+·017	+·091	−·091	·000
−25·8	−·021	+·039	+·018	+·076	−·075	+·001
−20·7	−·017	+·034	+·017	+·061	−·062	−·001
−15·4	−·013	+·027	+·014	+·045	−·047	−·002
−11·2	−·009	+·025	+·016	+·033	−·030	+·003
− 1·0	−·001	+·013	+·012	+·003	−·003	000
+ 3·9	+·003	+·010	+·013	−·011	+·011	000
+ 8·3	+·007	+·009	+·016	−·024	+·025	+·001
+11·9	+·010	+·003	+·013	−·035	+·032	−·003
+15·5	+·013	+·004	+·017	−·046	+·046	000

[1 unit = 300″, or 0·001 = 0″·3.]

This seems to show that the adopted time of nearest approach is very near the actual time.

The position of the star (B.D. +48°, 759) for 1900·0 is R.A. $2^{h}\ 41^{m}\ 26^{s}·2$, and Dec. +48° 51′ 22″·8 ; this is determined from measures on plate 1632.

The mean measured diameter from the 10 exposures is 16·7 for *Eros* and 18·0 for the star ; the star is given as 9·5 in B.D., so *Eros* was slightly fainter, probably 9·7 or 9·8 ; but scarcely so faint as the photographic magnitude assigned by Dr. Millosevich (10·9)—more nearly accordant with his visual magnitude (9·9).

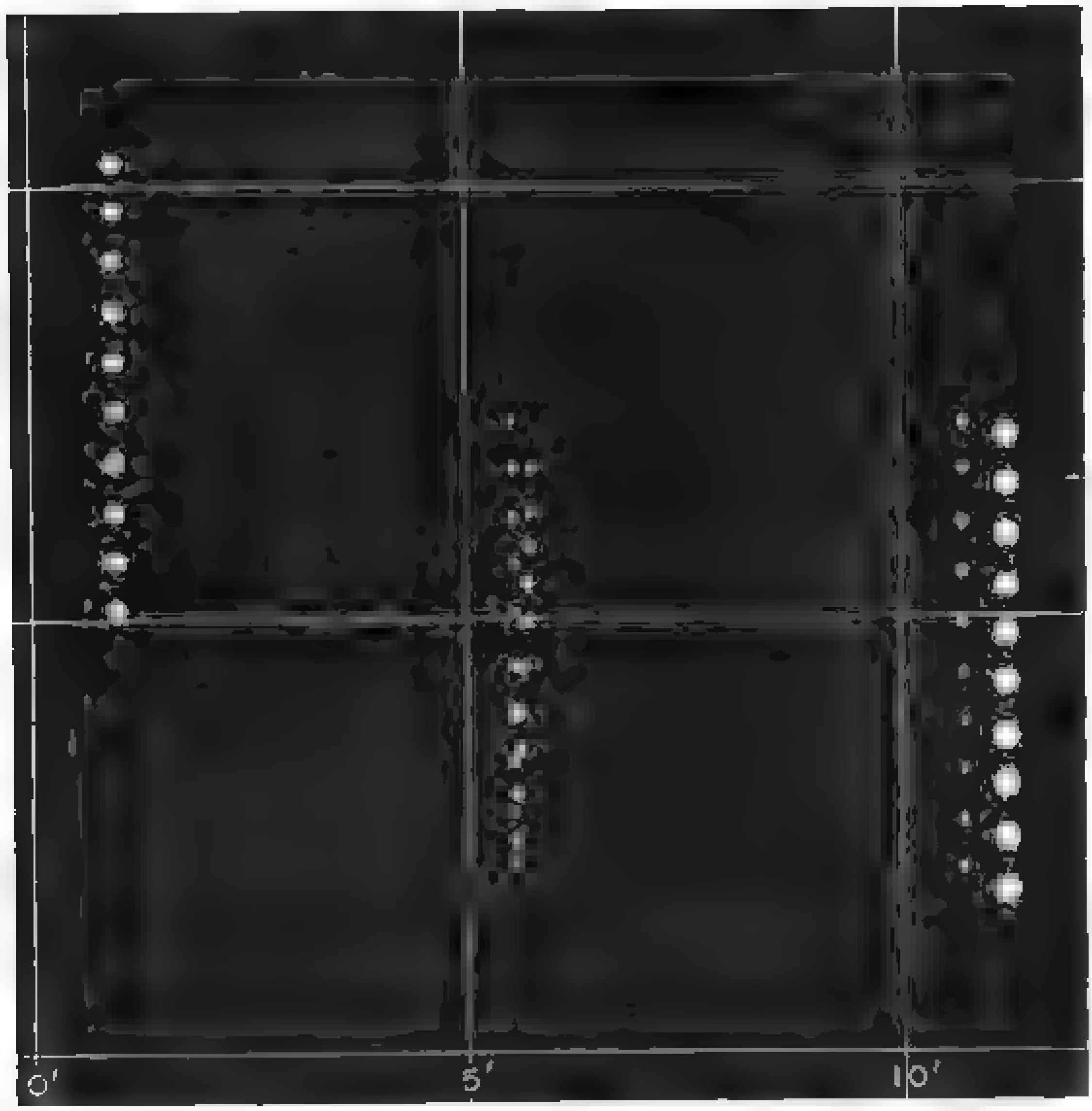
The most accurate ephemeris of the planet yet published is that given by Dr. Millosevich in *Astron. Nachrichten*, Nos. 3660, 3661, 3662. From comparisons with 5 plates the following corrections to this ephemeris have been found, assuming that the R.A. and Dec. given are referred to the true equinox of date.

Date. 1900.	Hour Angle. h	Correction to Ephemeris. s	″
Sept. 19	4½ East	− 0·87	+ 0·6
Oct. 5	6½ „	− 1·00	+ 0·8
5	3 West	− 0·92	+ 2·4
12	4½ East	− 1·31	+ 0·6
15	4 West	− 1·30	+ 0·5
28	5 „	− 1·46	+ 0·2

The reductions are entirely provisional, and may be slightly in error, *e.g.* on Oct. 5, though they have been examined. The

ephemeris published by Mr. Frank Robbins * is accordingly in error in R.A. by about 5^s on Sept. 19 and 14^s on Oct. 28; and in Dec. by about 1′.

Eros is now moving in a part of the sky where there are about 25 stars per square degree † shown on the B.D. charts. The total length of track in the seven months, September to March, is about 70°; and if we take a width of 5″ on each side, or 10″ altogether, the area covered by this path is 70/360, or 0·2



Eros is the image to the right of the central pair; the first exposure is at the top; motion north and west. Scale $7\frac{1}{2}$ times the original negatives.

square degree, which should thus contain 5 stars. An approach to some star of the B.D. within 5″ should thus take place about once in 6 weeks on the average. By securing photographs beforehand we could perhaps predict these approaches, which would afford good opportunities for micrometric measures.

* *Monthly Notices*, lx. p. 614.
† See diagram, *Monthly Notices*, lx. Plate 2.

Observations of Jupiter and his Satellites made at Mr. Crossley's Observatory, Bermerside, Halifax, during the Opposition 1899–1900. By Joseph Gledhill.

Owing to the low altitude of the planet and the bad observing conditions prevailing in the winter and spring of 1899–1900 very few observations could be made. On no occasion was the air steady enough for micrometer measures, and it was but seldom that a good view of the planetary details could be obtained. The structure of the North Tropical Belt was never really well seen; and unfortunately the details and changes of this belt have been for some years among the most interesting features of the planet. As in previous papers, the nomenclature used is that of the British Astronomical Association.

It may perhaps be worth noting that in the diagram on p. 45 of vol. lx. of the *Monthly Notices* the band numbered 1 should be single, not double. This band has for some years been a single straplike band.

The 9-inch Equatorial Refractor (photo-visual), by Messrs. Cooke, of York, was the instrument used. No power higher than 240, and that rarely, was ever used.

The Southern South Temperate Band.

This band always appeared a faint one, but on several occasions it was broader than the S. Temperate Band, *e.g.* May 15, 11^h; July 3, 9^h. At $8\frac{1}{2}^h$ July 26 it was noted as a narrow band. It was never an easy object, and was perhaps never really well seen.

The South Temperate Band.

This is the grey band so often described as *straplike* in previous papers. In some longitudes it appeared faint, in others a fairly strong grey band—*e.g.* it was faint at $10\frac{1}{2}^h$ May 24, faint and narrow at 9^h July 3, faint at 9^h July 10, and at 8^h July 17; it was narrow and well seen at $8\frac{1}{2}^h$ July 18, narrow at $8\frac{1}{2}^h$ July 26 and at $7^h\ 40^m$ August 15. It was described as "a well-marked band" at $9\frac{1}{4}^h$ July 17. In some longitudes it was broad and in others narrow, and the place where it changed from broad to narrow was seen on one or two occasions. The place where it changed from a faint to a darker band was on or near the central meridian at $9^h\ 5^m$ July 16, the darker portion being the western.

The South Tropical Belt.

This is the fine, double, dark belt, just S. of the equator. As in many past oppositions, so in this, its N. component has had many dark spots on its N. edge. As in past years, too,

the S. component has exhibited the well-known *p* shoulder, *f* shoulder, and the fainter portion of the belt preceding the *p* shoulder. In some longitudes (*e.g.* May 15 at 11^h) the N. component was the darkest band on the disc; in others both components were together fainter than the double band just N. of the equator (North Tropical Belt)—*e.g.* May 24, $10\frac{1}{2}^h$, and at 9^h July 10. In some longitudes the components are well separated—*e.g.* June 17, $9\frac{1}{2}^h$; in others they are almost in contact. The upper (S.) component was the darkest band on the disc at 9^h July 3. On July 10, 9^h, the two bands were well separated along the *f* half. On July 18, $8\frac{1}{2}^h$, this southern double band was wider and darker than the N. Tropical Belt, much darker at 8^h 20^m August 15, and wider on August 16, 7^h.

The North Tropical Belt.

This fine, double, dark band has in some longitudes lost some of its depth of tone since the last opposition. On the other hand it has decidedly gained in warm colour. During the late opposition I was never able to see its intricate structure well. The colour just mentioned was strikingly seen at $10\frac{1}{2}^h$ May 24. On July 16, 9^h, the western half was darker than the eastern half. The numerous bright and dark spots on it were often seen, but rarely well enough for clear description or transit observations. The band as a whole has lost its old sharpness.

The North Temperate Band.

A faint band was often seen in this region.

The Central or Equatorial Zone.

Most of the warm colour has left this zone; indeed, it differs very little in point of colour from the rest of the disc.

The brightest zone was always that between the South Tropical Belt and the South Temperate Band.

The Red Spot was not seen on any occasion, owing, no doubt, to the low altitude of the planet and the violent motion.

The faint, narrow, and often interrupted band in the Equatorial Zone was often seen—*e.g.* May 24, $10\frac{1}{2}^h$; June 17, $9\frac{1}{2}^h$; July 3, 9^h; July 16, 9^h; July 18, $8\frac{1}{2}^h$; August 15, 7^h 40^m.

Bright and Dark Spots.

Dark spots under the South Tropical Belt were seen on perhaps every night when the planet was visible; and some were seen on the North Tropical Belt. Some bright spots also were seen. Few transits of any value could be obtained owing to the great motion.

July 1, 9^h. A large, bright spot seen under (to N. of) the S. Tropical Belt; on central meridian about 9^h.

July 16, $9^h\ 14^m$. A bright gap in the S. Temperate Band was on central meridian.

July 17. Two bright spots or gaps were seen in the N. component of the S. Tropical Belt. One was on the central meridian about $9^h\ 17^m$. A dark spot on the N. component of the N. Tropical Belt was on the central meridian about $9^h\ 21^m$.

July 18. At about $9^h\ 2^m$ a bright spot or gap in the S. Temperate Band was on the central meridian.

August 15. At about $8^h\ 8^m$ a dark spot on the N. edge of the N. component of the S. Tropical Belt was on the central meridian. Two bright gaps in the N. Tropical Belt were also seen. One of them was on the central meridian about $8^h\ 17^m$.

August 16. A long, dark spot on the N. edge of the S. Tropical Belt was on the central meridian about $7^h\ 43^m$. A bright gap in the S. Temperate Band was seen about the same time to the W. of the central meridian.

August 20. Two bright gaps were seen in the N. Tropical Belt at $7^h\ 24^m$.

August 27. A bright gap in the N. component of the N. Tropical Belt was central about $8^h\ 8^m$. A little in advance there was another bright gap in the same belt.

Phenomena of Jupiter's Satellites.

II. Tr. I. External contact at $8^h\ 54^m$ July 10; visible on the disc till after $9^h\ 20^m$. I. Ec. R. First seen, through thin cloud, at $10^h\ 25^m\ 44^s$ July 12. III. Sh. I. Just fully on the disc at $8^h\ 43^m$ July 17.

II. Oc. R. External contact at $7^h\ 27^m$, and II. Ec. D. last seen at $7^h\ 38^m\ 0^s$ August 20.

On the Appearance of Saturn's "Crape" Ring in 1900.
By E. M. Antoniadi.

Since the publication of the two papers in vol. lix., pp. 498 and 586, of the *Monthly Notices*, the writer has tried to follow the deportment of the dark ring as affected by the varying heights of the Sun and Earth above the plane of the system.

Owing to the fact that the mirror of the great Paris siderostat could not be pointed so as to make a smaller angle than 12° with the vertical, observations of *Saturn* at $-22\frac{1}{2}°$ of declination were rendered impossible with the large telescope. At Juvisy, with the $9\frac{3}{4}$-inch equatorial, nothing abnormal could be detected until the beginning of autumn. On 1900 October 2 the following peculiarities were noted again and again during the fugitive moments of very sharp seeing :—

1. The "crape" ring seemed of uniform intensity across the planet.

2. Its breadth on minor axis was greater than what ought to be expected from its breadth on major axis; indeed, along the minor axis, it appeared broader than the outermost ring, occupying fully three-tenths of the total breadth of the system.

3. Its inner edge in front of *Saturn* was much more concave than the outer edge; more so than would be anticipated from the divergence of two concentric elliptical arcs. Meantime, the inner edge across the planet did not seem to form the continuation of the edge projected on the sky. But this observation was rendered exceedingly difficult and uncertain on account of the low altitude of *Saturn* and the concomitant strong absorption of the "dark" ring's feeble light.

Now, at the date of these observations we had

$$l-l'=0^\circ 43',$$

a value which, taken in connection with the facts enunciated, tends to militate against the notion of a *dark* ring. Owing, however, to the smallness of $\Delta=43'$, these results cannot be considered decisive, almost grazing, as they do, observational errors. The question will be elucidated by the greater values of Δ in coming years.

Observatoire Flammarion, Juvisy (S.-et-O.):
1900 *October* 12.

Occultations of Saturn, 1900 *June* 13 *and September* 3, *observed at the Radcliffe Observatory, Oxford.*

(*Communicated by the Radcliffe Observer.*)

The following observations of two occultations of *Saturn* were made at this Observatory:—

1900 *June* 13.

Phenomena.	Observer.	Reappearance (at Dark Limb of Moon). Observed G.M.T.
Ring—		h m s
1st trace	R.	10 49 51·1
2nd contact	,,	10 50 1·6
Ball—		
1st contact	,,	10 50 20·0
Ring—		
3rd contact	,,	10 51 3·9
Last ,,	,,	10 51 11·9

Observer's Remarks.

Saturn very faint; reappeared near bright, but defective,

limb of the Moon. Observations made with the Barclay Equatorial, using power 90.

1900 *September* 3.

Phenomena.	Disappearance (at Dark Limb of Moon). Observed G.M.T. A. A. R.	W.	R.	Reappearance (at Bright Limb of Moon). Observed G.M.T. A. A. R.	W.	R.	Reference to Remarks.
Ring—	h m s	s	s	h m s	s	s	
1st contact	7 12 ...	50·2	50·4	8 8 50·8	57·3	49·2	(*a*)
2nd „	7 12 ...	58·5	56·9	8 8 54·8	63·1	55·2	
Ball—							
1st contact	7 13 2·5	2·9	1·9	8 9 7·3	10·0	3·1	(*b*)
Bisection	7 13 ...	24·3	...	8 9 ...	32·2	...	
Last contact	7 13 56·4	57·3	54·2	8 9 41·2	47·9	33·1	
Ring—							
3rd contact	7 14 12·4	10·7	12·7	8 9 45·2	56·5	36·6	(*c*)
Last „	7 14 31·3	31·0	30·1	8 9 57·2	62·4	59·0	(*d*)

Observers' Remarks.

Disappearance:—

[A. A. R.] Thin cloud throughout. (*b*) Doubtful. (*c*) Possibly 1ˢ too early.

[W.] Observation very difficult, made through hazy cloud. No satellites visible. The points observed are those where the major axis of the ring would cut the ring and ball.

[R.] Images diffused; sky hazy. Observations difficult. (*a*) May be 1ˢ late. (*b*) A lingering contact.

Reappearance:—

[A. A. R.] (*a*) Likely to be good, as attention was concentrated at the very point of limb where planet reappeared. (*c*) May be a little too soon. The colour of ring and ball appeared much greyer than that of the Moon.

[W.] (*a*) Was looking exactly at place of reappearance. The light of *Saturn* looked ashy grey compared with the yellow disc of the Moon. The limbs of planet and Moon were much steadier than at disappearance. As the planet emerged obliquely, the same points along the axis of the ring were observed as at disappearance. After emergence, the major axis of *Saturn's* ring, when produced to cut the limb of the Moon, formed with a tangent to the Moon's limb (drawn at the point of intersection) an angle of about 30°.

[R.] Observations difficult. (*a*) Ring faint, but first trace caught. This observation considered satisfactory. (*d*) Contact lingered. Part of the ring appeared to be thinly veiled by a narrow band of shade adjacent to the Moon's limb.

[*Note added later*.—(*c*) The observer considers his observation of the 3rd contact of ring entitled to but little weight.]

At reappearance, both A. A. R. and R. have, for the 1st and 2nd contacts with the ring and for the 1st contact with the ball, observed the moment at which any part of the outline of ring or ball first emerged from behind the limb of the Moon; and for the 2nd contact with the ball and the 3rd and 4th contacts with the ring the first moments at which the limb of the Moon and the outline of the ring or ball were completely separated; whereas W. noted the times of emergence of the several points where the major axis of the ring cut the ring and ball.

Observers (September 3):—

[A. A. R.] Dr. Rambaut. Barclay equatorial, 10-inch aperture. Powers: 180, disappearance; 85, reappearance.

[W.] Mr. W. Wickham. Marlborough telescope, 3·2-inch. Power, 75. Observations recorded on the chronograph.

[R.] Mr. W. H. Robinson. Heliometer, 7·5-inch (one segment only). Powers: 200, disappearance; 80, reappearance.

Radcliffe Observatory, Oxford:
1900 *November* 6.

Occultation of Saturn, 1900 *September* 3. By the Rev. S. J. Johnson, M.A.

The occultation of *Saturn* on this evening took place under similar circumstances to that which I witnessed on 1870 September 30, the sky being on both occasions singularly clear, the disappearance being about half an hour after sunset, the Moon not far from the first quarter, and the objects nearly at the same point in the sky.

I employed power of 100 on $3\frac{3}{4}$-inch equatorial.

At $7^h\ 10^m\ 17^s$ the preceding ansa of the ring already in contact with the Moon's limb.

$7^h\ 11^m\ 1^s$. Globe of *Saturn* reached.
$7^h\ 11^m\ 54^s$. Globe covered.
$7^h\ 12^m\ 30^s$. Following ansa of ring immerged.

At the reappearance, owing to the dull faint colour of the planet, it had begun to come out a few seconds before being distinctly perceived.

At $8^h\ 6^m\ 53^s$. Globe began to emerge.
$8^h\ 7^m\ 40^s$. Globe entirely emerged.
$8^h\ 7^m\ 59^s$. Last contact with following ansa of ring.

The planet disappeared gradually with uniform motion, and clear definition. At emersion, the difference of brilliancy between the bright yellow limb of the Moon and the grey disc of the planet was most striking. One could not but be impressed with the marked contrast with the brightness of *Jupiter* when close to the Moon at his occultation four years ago last June.

Melplash Vicarage, Bridport:
November 2.

Photographic Measures of the Ring Nebula in Lyra and of the Neighbouring Faint Stars. By F. P. Leavenworth.

(*Communicated by the Secretaries.*)

In response to Professor Barnard's request for observations of the faint stars near the Ring Nebula of *Lyra* (see *Monthly Notices, R.A.S.*, January 1900), the following measurements are published. They are measures of photographs taken with the $10\frac{1}{2}$-inch refractor of the University of Minnesota.

Observations of position-angle and distance were made with a Repsold measuring machine, exactly as a double star is measured with a filar micrometer or an ordinary visual telescope. Each measure was repeated with the angle rotated through 180°.

The orientation was found by reading the angle of a star trail on the plate.

Since the distances measured were very small, never more than one and one-half millimetres, variation of scale value and other small corrections were found to be negligible quantities. The amount of time consumed in measurement and reduction was therefore not greatly in excess of that employed in ordinary double-star measures.

Corrections were applied for division error of scale, error of run and refraction. In addition a correction to the reading of the circle for orientation had to be introduced because the trail was not at the middle of the plate. If c = this correction and d = the distance of the trail from the middle of the plate,

$$c = d \tan \delta$$

plus if the trail is east. The greatest value of c was about 0°·5.

The adopted scale value for all four plates was one millimetre $=59''{\cdot}64$.

The plates were taken as follows :—

			h	m		
I.	Sept. 1, 1897	Exposure	1	23	Night	poor.
II.	Nov. 1, 1899	,,	2	4	,,	fair.
III.	Apr. 1, 1900	,,	1	42	,,	good.
IV.	June 5, ,,	,,	2	5	,,	good.

The nucleus of the nebula was a clearly defined spot which could be accurately measured. Star b was too indistinct to be observed except on plate 2, and c was scarcely stronger ; f could not be accurately measured on account of the blurring of the components.

Plate III. was measured by three members of the class in astronomy, Miss Harriet Dunton, Miss Louise Goulding, and Mr. Albert Lehman. Their names are indicated by the initials D., G., L. This being their first experience in photographic

measurements, each made a complete set of measures of the same plate. For this reason the separate results are given; and also to show what accuracy may be expected from measures repeated on the same plate. Plates I., II., and IV. were measured by myself.

The probable errors are $\pm 0^\circ \cdot 14$ and $\pm 0'' \cdot 18$ for the values of a position-angle and distance from a single plate.

Measures of Plate III.

Nucleus and *a*.

	°	″
D.	88·98	60·65
G.	89·24	60·30
L.	89·54	59·76

Nucleus and *d*.

D.	299·38	82·07
G.	299·47	81·93
L.	299·70	81·57

Nucleus and *e*.

D.	312·88	71·71
G.	313·25	71·71
L.	312·57	70·85

Nucleus and *g*.

D.	32·72	90·27
G.	33·13	90·25

Nucleus and *h*.

D.	121·08	113·70
G.	121·50	113·93

a and *d*.

	°	″
D.	286·47	137·18
G.	286·47	137·66
L.	286·44	137·46

a and *e*.

D.	292·82	122·25
G.	292·76	122·25
L.	292·75	122·29

a and *g*.

D.	350·76	75·78
G.	350·62	77·02
L.	350·39	76·64

a and *h*.

D.	148·47	70·45
G.	148·69	70·60
L.	148·50	70·56

Nucleus and *a*.

	°	″
1897·671	89·48	60·42
1899·837	89·35	60·83
1900·248	89·25	60·24
1900·428	89·10	60·73
1899·55	89·29	60·56

Nucleus and *b*.

1899·837	186·61	65·17

Nucleus and *c*.

1899·837	268·12	55·12
1900·428	269·53*	55·56*
1900·13	268·82	55·34

* Image double.

Nucleus and *d*.

1899·837	299°·86	81″·74
1900·248	299·52	81·86
1900·428	299·95	82·31
1900·17	299·78	81·97

Nucleus and *e*.

1897·671	312·62	71·66
1899·837	313·04	71·16
1900·248	312·90	71·32
1900·428	312·65	71·12
1899·55	312·80	71·32

Nucleus and *g*.

1899·837	32·49	89·59
1900·248	32·72	90·26
1900·428	32·10	90·53
1900·17	32·50	90·13

Nucleus and *h*.

1897·671	121·12	113·67
1899·837	121·08	114·12
1900·248	121·29	113·82
1900·428	121·23	113·74
1899·55	121·18	113·84

a and *b*.

1899·837	225·57	94·38

a and *c*.

1899·837	268·63	115·38
1900·428	268·63	115·72
1900·13	268·63	115·55

a and *d*.

1899·837	286·90	137·14
1900·248	286·46	137·43
1900·428	286·91	137·74
1900·17	286·76	137·44

a and *e*.

1897·671	292°·60	122″·88
1899·837	292·88	122·14
1900·248	292·78	122·26
1900·428	292·57	122·20
1899·55	292·71	122·37

a and *g*.

1899·837	350·14	76·12
1900·248	350·59	76·48
1900·428	350·22	76·78
1900·17	350·32	76·46

a and *h*.

1897·671	148·54	70·41
1899·837	148·70	70·50
1900·248	148·56	70·54
1900·428	148·57	70·24
1899·55	148·59	70·42

Considering the great difference in the size of the telescopes, in the methods used, and in the difficulty of the objects measured, the agreement with Professor Barnard's measures is very good, and confirms his results. There is without doubt a difference of 1°·4 and 1″ between Burnham's measures of the nucleus and *a* and the present value. And it seems very probable that there is motion in one of these objects.

The complete list of measures of nucleus and *a* are as follows :—

Burnham	1891·45	87°·8	61″·69	5
Scheiner	1894·83	89·07	60·85	1
Barnard	1898·60	88·77	60·70	5
„	1899·48	89·14	60·66	5
Leavenworth	1899·55	89·29	60·56	4

In a letter to the writer Professor Barnard has corrected the values of his distances, having obtained a better value of a revolution of the micrometer screw; and in Dr. Scheiner's measure I have, at Professor Barnard's request, used only the measure made by the former.

The magnitudes of the stars were determined by the sequence method. When compared with Professor Barnard's values

(*Monthly Notices* vol. lx. p. 248), and reduced by them to magnitudes, a very close agreement is obtained, as appears below :—

Star	Step.	Mag. B.	Mag. L.
a	0	12·2	12·2
h	25	12·8	13·1
n	27	...	13·1
e	28	13·2	13·2
f	40	13·7	13·6
g	43	13·7	13·7
d	44	13·5	13·8
c	49	14·0	14·0
b	52	13·8	14·1

University of Minnesota, Minneapolis :
1900 *September.*

Observations of Nebulæ made at the Chamberlin Observatory, University Park, Colorado. By Herbert A. Howe.

(*Communicated by the Secretaries.*)

The accompanying notes on nebulæ are a by-product of the series of measurements made with the Bruce micrometer on the 20-inch equatorial refractor, during the twelve months ending 1900 June 30. They are corrections of or additions to our previous information, and form a continuation of the notes published in former numbers of the *Monthly Notices*, the last being in the issue for 1899 December. When the position of a nebula is given below it is to be understood that the position previously published in the N.G.C. or *Index Catalogue*, or in some later list sent out by the discoverer, is erroneous by at least ten seconds in right ascension or two minutes in declination. Usually the errors are much larger than these. All positions are referred to the mean equinox of 1900·0.

It has seemed best to divide the nebulæ mentioned into three lists. The first contains those found in the N.G.C., arranged in the order of their current numbers. The second list is made up from the *Index Catalogue*. All nebulæ taken from it have their current numbers enclosed in brackets, to distinguish them from those in the N.G.C. The third list consists of nebulæ found by Swift at the Lowe Observatory in recent years. All but one of them are found in *A.N.* 3517, and are designated by affixing their current numbers in that publication to the word Swift. The one exception, which I have called "Swift 12, 3," is taken from the *Monthly Notices*, vol. lix. No. 10, p. 568. The words "minutes" and "seconds" refer to time only. A few of the notes are about clusters which have been examined.

Nebulæ from the N.G.C.

17 and 34. I was unable to find 17 in the N.G.C. position for it, though, according to its description by Müller, it should not be difficult with my telescope. I judge it to be identical with 34, which follows two minutes at nearly the same declination. Müller says of 17 "D * 2′ p," which is true of 34, which follows a double 8 seconds, 0′·1 south. The double is of mags. 10–11, angle 280°, and distance 6″. There is no double near the N.G.C. place for 17, except two faint stars about 50″ apart. The position of the nebula is $0^h\ 6^m\ 0^s$, $-12°\ 39'{\cdot}7$.

45. The "L * cont. f" is of mag. 9. There is a star of mag. 7 about 5′ south preceding the nebula. The N.G.C. right ascension is ten seconds too small.

64. The position is $0^h\ 12^m\ 24^s$, $-7°\ 22'\ 8$.

65. The position is $0^h\ 13^m\ 56^s$, $-23°\ 26'{\cdot}1$.

66. The "* 9 n 1′" follows the nebula 1 second, 1′·5 north. The position of the nebula is $0^h\ 14^m\ 2^s$, $-23°\ 29'{\cdot}5$.

77. This may be simply an extremely faint star. The "* 9 p 3′" appears to be of mag. 10, and precedes 13 seconds, 0′·6 north. The position of the nebula is $0^h\ 14^m\ 59^s$, $-23°\ 5'{\cdot}2$.

100. This is 2′ long, and very narrow, the elongation being at 225°. It contains some condensations, but the moon was too bright at the time of observation to allow me to locate them definitely.

142, 143, and 144. The N.G.C. calls each "e F," the first two "S," and 144 "v S." The facts are that 144 is the brightest and largest, 143 next in size and brightness, and 142 faintest and smallest. Their positions are :—

			h	m	s	°	′
142	...	...	0	26	8,	−23	10·2.
143	...	...	0	26	16,	−23	6·7.
144	...	...	0	26	20,	−23	11·8.

150. One spot near the north preceding end of this pretty large nebula is brighter than the rest. The position of this spot is $0^h\ 29^m\ 18^s$, $-28°\ 21'{\cdot}2$.

161. The discoverer says "nearly bet. 2 st." The stars are of mags. 8 and 9·5 respectively. A sketch shows that the first is about 6′ north preceding the nebula, while the second is south following at a distance of 4′ or 5′. I noticed another nebula 2′ south of 161. The position of 161 is $0^h\ 30^m\ 28^s$, $-3°\ 23'{\cdot}9$.

166. The "* 11 np" seemed to me to be of mag. 10, and preceded 17 seconds, 2′·8 north. The position of the nebula is $0^h\ 30^m\ 47^s$, $-14°\ 9'{\cdot}7$.

167. The position is $0^h\ 30^m\ 24^s$, $-23°\ 55'.6$.

168. The "* 10 nf 3′" is 2′.5 north, and follows 7 seconds. The position of the nebula is $0^h\ 31^m\ 40^s$, $-23°\ 8'.6$.

172. There is a star of mag. 13 close south preceding. The position of the nebula is $0^h\ 32^m\ 15^s$, $-23°\ 8'.3$.

177. Müller queried whether this were a star. It seemed to me to be a nebula.

179. The "B * np" is of mag. 8·5, and precedes a few seconds, about 5′ north. The position of the nebula is $0^h\ 32^m\ 46^s$, $-18°\ 23'.9$.

187. The position is $0^h\ 34^m\ 29^s$, $-15°\ 12'.3$.

190. The "sev. st nr sp" are all of less than mag. 10. There is one of mag. 12·5 which lies about 30″ due south of the nebula. Had the Moon been absent at the time of observation, perhaps the nebula would have been seen to extend to this star.

235. The nucleus of this is of mag. 11, so that it is favourable for measures of parallax. A star of mag. 9 lies 3′.5 north, a fraction of a second preceding.

276. Instead of a "* 11 n 3′" I find one of mag. 8, a close double, 4′ or 5′ (by a sketch) north following. There is a star of mag. 11, which is 3′.0 south, 6 seconds following. The position of the nebula is $0^h\ 47^m\ 12^s$, $-23°\ 13'.3$.

320. The "* 10 n" precedes 2 seconds, 1′.3 north. The position of the nebula is $0^h\ 53^m\ 52^s$, $-21°\ 22'.8$.

335. The position is $0^h\ 54^m\ 24^s$, $-18°\ 46'.4$.

363. The position is $1^h\ 1^m\ 19^s$, $-17°\ 4'.7$.

369. The position is $1^h\ 0^m\ 13^s$, $-18°\ 17'.7$.

417. The position is $1^h\ 6^m\ 11^s$, $-18°\ 40'.8$.

487. The position is $1^h\ 17^m\ 2^s$, $-16°\ 53'.5$.

554. The "* 11 f" follows 8 seconds, 0′.3 north. The position of the nebula is $1^h\ 22^m\ 23^s$, $-23°\ 14'.6$.

555. The position is $1^h\ 22^m\ 25^s$, $-23°\ 16'.8$.

556. This is fainter than 555, which in turn is fainter than 554; the three are close together. The position of 556 is $1^h\ 22^m\ 26^s$, $-23°\ 14'.9$.

580. The position is $1^h\ 25^m\ 36^s$, $-2°\ 30'.5$.

583. The position is $1^h\ 24^m\ 53^s$, $-18°\ 51'.3$.

648. The position is $1^h\ 33^m\ 50^s$, $-18°\ 20'.3$.

655. The position is $1^h\ 37^m\ 1^s$, $-13°\ 35'.2$.

667. Müller says "* 10 np 100″." It precedes the nebula 5 seconds, 0′.8 north. The nebula differs very little in appearance from a star of mag. 13·5. Its position is $1^h\ 40^m\ 14^s$, $-23°\ 25'.1$.

701. The elongation is at 210°.

725. The position is $1^h\ 47^m\ 47^s$, $-17°\ 0'.6$.

756. The position is $1^h\ 49^m\ 41^s$, $-17°\ 11'.9$.

836. The position is $2^h\ 5^m\ 47^s$, $-22°\ 31'.5$.

837. The position is $2^h\ 5^m\ 39^s$, $-22°\ 54'.3$.

849. The discoverer says "? neb." The object is as bright as

a star of mag. 12, and appeared to me a trifle un-starlike. I could see nothing else which appeared nebulous in the neighbourhood.

856. The "F ✱ close f" is of mag. 11, and follows 3·5 seconds, 0′·3 north.

858. The position is $2^h\ 7^m\ 53^s$, $-22°\ 56'\cdot4$.

859. This is near 856 and 868, both of which are called "e F" by their discoverer, while 859 is called "p F." Yet, on the night on which I measured both 856 and 868 I was utterly unable to find their supposed brighter neighbour 859. Swift discovered 859 and 868 on the same night.

863. This contains a small nucleus of mag. 12, which is much brighter than the circumjacent nebulous matter.

866. This, like 859, I could not see on the night when I measured its supposably much fainter neighbours 856 and 868. Swift discovered 866 and 868 on the same night.

878. The position is $2^h\ 13^m\ 19^s$, $-23°\ 50'\cdot7$.

899. The "D✱p" is composed of two stars of mag. 10·5, widely separated. The nearer of the two precedes the nebulæ 5^s, 0′·9 south.

908. The nucleus is of mag. 13.

966. The "✱9 s p 2′" is of mag. 9·5, and precedes 1 second, 0′·6 south. The position of the nebula is $2^h\ 27^m\ 10^s$, $-20°\ 19'\cdot5$.

1034. The N.G.C. right ascension seems to be a minute out. The discoverer says "2 B st p 20^s." In that place I see two stars of mags. 11 and 12. The position of the nebula is $2^h\ 33^m\ 30^s$, $-16°\ 14'\cdot4$.

1098. This has a good nucleus of mag. 12·5. The position is $2^h\ 40^m\ 13^s$, $-18°\ 4'\cdot9$.

1099. The position is $2^h\ 40^m\ 38^s$, $-18°\ 7'\cdot8$

1100. The position is $2^h\ 40^m\ 56^s$, $-18°\ 6'\cdot6$.

1103. The "✱ 11 f" follows $1\cdot5^s$, 0′ 2 north. Another similar nebula precedes this nebula 2^s, 2′·0 south.

1105. I found nothing in the N.G.C, place for this, but 4^m following was a very small nebula, about equal in brightness to a star of mag. 13. As Leavenworth observed his nebula only once, and took its place roughly, the two may be identical. The position is $2^h\ 47^m\ 36^s$, $-16°\ 7'\cdot1$.

1119. The position is $2^h\ 43^m\ 38^s$, $-18°\ 24'\cdot2$.

1120. The position is $2^h\ 44^m\ 20^s$, $-14°\ 53'\cdot2$.

1140. This very small object is about equivalent in brightness to a star of mag. 10.

1148. This has a sharp nucleus of mag. 13.

1163. The position is $2^h\ 55^m\ 44^s$, $-17°\ 32'\cdot9$.

1182 and 1205. The descriptions of these given by their discoverer in No. 146 of the *Astronomical Journal* agree closely, except in regard to the angle of elongation. Their rough right ascensions there given differ 3^m. Having

examined the locality very carefully on two fine nights I judge the objects to be identical. The " * 9·5 3′ sp " precedes 8ˢ, about 2′ south. The position of the nebula is $2^h\ 58^m\ 38^s$, $-10°\ 3'{\cdot}7$.

1187. This appears to contain two condensations, of mags. 13 and 13·5, the southern one being the brighter. Possibly the fainter is just outside the nebula.

1188. The position is $2^h\ 59^m\ 3^s$, $-15°\ 52'{\cdot}5$.

1189. The position is $2^h\ 58^m\ 44^s$, $-16°\ 0'{\cdot}8$.

1190. The position is $2^h\ 58^m\ 46^s$, $-16°\ 3'{\cdot}0$.

1191. The position is $2^h\ 58^m\ 50^s$, $-16°\ 4'{\cdot}5$.

1201. This, being pretty bright and pretty small, is good for parallax observations. A star of mag. 10 precedes $5{\cdot}5^s$, $2'{\cdot}6$ north.

1203. Leavenworth says " neb ? " It is extremely faint and very small, and lies nearly midway between two stars of mags. 8·5 and 9. The brighter star precedes 10^s, $1'{\cdot}1$ south.

1204. The discoverer says in the original announcement in No. 146 of the *Astronomical Journal*, " B * and sev Fst inv in neb." I noticed simply a small triangle of stars of mags. 11, 12, and 13. The brightest star seemed to be enveloped in an extremely faint mantle of nebulous matter. The position of this star is $2^h\ 59^m\ 54^s$, $-12°\ 44'{\cdot}1$.

1228. The position is $3^h\ 3^m\ 45^s$, $-23°\ 18'{\cdot}4$.

1229. This has nearly the same right ascension as 1228, but precedes it a little, contrary to the description " f of 2," in the N.G.C. The position is $3^h\ 3^m\ 45^s$, $-23°\ 20'{\cdot}6$.

1230. The N.G.C. says " ? F *." The object is almost a star of mag. 12·5, but there is some extremely faint nebulous matter about it. The position is $3^h\ 3^m\ 50^s$, $-23°\ 22'{\cdot}1$.

1262. The position is $3^h\ 10^m\ 55^s$, $-16°\ 14'{\cdot}9$.

1263. The position is $3^h\ 11^m\ 0^s$, $-15°\ 28'{\cdot}1$.

1289. The " 4 st f " are of about mag. 10, and are not close together, the farthest being perhaps 10′ from the nebula. The nearest follows the nebula 13^s, $1'{\cdot}8$ south. The position of the nebula is $3^h\ 13^m\ 46^s$, $-2°\ 20'{\cdot}2$.

1290. The position is $3^h\ 14^m\ 43^s$, $-14°\ 21'{\cdot}1$.

1295. Of this Stone says " * 10 f 3′." The star follows 13^s, $0'{\cdot}5$ north. The position of the nebula is $3^h\ 15^m\ 22^s$, $-14°\ 21'{\cdot}5$.

1296. The position is $3^h\ 14^m\ 6^s$, $-13°\ 25'{\cdot}6$.

1325. There is a nuclear condensation of mag. 13·5. The " * 9·5 att " follows this condensation 3^s, $0'{\cdot}3$ north.

1359. This was observed in moonlight, but seemed to have a nucleus of mag. 13.

1368. The position is $3^h\ 30^m\ 22^s$, $-15°\ 59'{\cdot}4$.

1371. The centre of this " p B " nebula is of mag. 11.

1391 and 1394. On p. 214 of the N.G.C. is the following note

about these nebulæ. "Nos. 373–74 of Prof. O. Stone's list, *Astronomical Journal*, No. 152, with these notes added: '1st of 3, one of which is G.C. 742,' and '3rd of 3.'" The facts are that G.C. 742 is the first of the three, 1391 the second, and 1394 the third. Micrometrical measures of the three are to be found on pp. 190–1 of Part 6 of Vol. I. of the Publications of the Leander McCormick Observatory. According to these measures the position of 1391 for 1860·0 is $3^h\ 32^m\ 34^s$, 108° 48′·8. On p. 225 of the *Index Catalogue* the N.P.D. of 1391 (derived from the measures mentioned above) is incorrectly given as 108° 45′·0. My measures of both nebulæ agree with those obtained at the McCormick Observatory.

1405. I did not notice the "F st inv" which are mentioned by the discoverer. The position is $3^h\ 35^m\ 43^s$, −15° 51′·3.

1414. The position is $3^h\ 37^m\ 8^s$, −22° 0′·0.

1450. The position is $3^h\ 40^m\ 48^s$, −9° 32′·8.

1452. The position is $3^h\ 40^m\ 53^s$, −18° 56′·7.

1509. The position is $3^h\ 59^m\ 11^s$, −11° 27′·2.

1568. The discoverer says, "nearly bet. 2 st." They are of mag. 10. The nearer one follows the nebula 3^s, 0′·6 north.

1575 and 1577. These are identical, Swift's position for 1577 being nearly correct. The "* nr s" of 1577, and the "* 9·5 s 2′" of 1575 are the same. This star follows the nebula 1^s, 2′·1 south. The central part of the nebula is of mag. 13.

1583. The position is $4^h\ 23^m\ 52^s$, −17° 49′·0.

1584. The position is $4^h\ 23^m\ 41^s$, −17° 44′·6.

1594. The position is $4^h\ 25^m\ 57^s$, −6° 0′·9.

1631. No description of this was given by h; I found it to be very faint and small.

1686. The position is $4^h\ 48^m\ 23^s$, −15° 30′·6.

1780. The position is $5^h\ 2^m\ 0^s$, −19° 36′·1.

1886. Instead of a "* 8 s p 40″" I find that a star of mag. 9 precedes 11^s, 0′·9 south. A star of mag. 8·5 is about twice as far away, nearly due south.

1889. This is given in the N.G.C. as a "Ld R" nebula, and is said to be a close double with 1888. I examined the locality on one night, when the seeing was excellent, and found a faint star close following 1888; I could, however, see no evidence of its nebular character. I suspected something excessively faint about 10^s following the nebula, but thought that "Ld R" would scarcely describe it as a close double with 1888.

1906. The position is $5^h\ 20^m\ 18^s$, −16° 2′·0.

1964. This appeared to contain one star of mag. 11, and three of mag. 12. The seeing was not good at the time of observation. H called the nebula "v S," but it is large.

2054. This was discovered by G. P. Bond, its description in

the N.G.C. being "vF, pS, iR, r? * 9—10 7′n." It appears to be simply a small triangle composed of two stars of mag. 12, and one of mag. 13. They are 7′ south of a star of mag. 9. No trace of nebulosity was visible, though the seeing was fine.

2280. The centre of this nebula is equal in brightness to a star of mag. 13.

2352. I saw nothing noteworthy in the place given for this cluster, except that the whole background of the sky in the vicinity contains myriads of minute stars, on the limit of vision.

2359 and 2361. In *Monthly Notices*, lviii., 9, on p. 518, there is a note to the effect that 2361 is a condensation in 2359. I have studied these objects on three more nights. 2359 is 6′·5 long, north and south, and its average breadth is 3′. It is much narrower in the centre than at the ends, the west side containing a deep notch. 2361 seems, as previously, to be simply the brightest part of 2359. It is possible that Bigourdan, when observing 2361, did not see the large extent of very faint nebulosity surrounding it, and constituting 2359. The N.G.C. right ascension of 2359 is a minute too small; if this error was also in Herschel's *General Catalogue*, Bigourdan may naturally have concluded that his nebula, 2361, was not identical with H's nebula, 2359. The northern edge of 2359 is bounded by a straight row of four stars of mag. 11. The southern half of the nebula is brighter than the northern.

2362. This cluster is 5′ in diameter, and consists of stars from mag. 10 down, surrounding 30 Can. Maj. The large star is in the centre.

2367. The stars in this cluster are few and scattered, being from mag. 10 down. There is one double of mags. 10—10, angle 95°, and distance 4″.

2374. The diameter of the cluster is 15′; the stars are irregularly scattered, and not particularly numerous; none are brighter than mag. 10.

2382. In *Monthly Notices*, lviii. 9, p. 518, an unsuccessful search for 2382 is noted. The trouble seems to have been that the N.G.C. declination is about 10′ out, and the right ascension 18^s in error. The position is $7^h\ 19^m\ 52^s$, $-27°\ 20'·0$.

2479. The stars are scattered, and form curves and straight lines, no one being brighter than mag. 10·5. The diameter of the group is about 10′.

2482. The diameter of the cluster is 20′. There is one star of mag. 9 in the preceding part of the cluster; none of the rest are brighter than mag. 10·5.

2483. In this the stars are from mag. 10 down.

2509. In this beautiful little cluster the stars are quite faint; there is one spot in it where the stars are closely

crowded, giving a nebulous gleam. The average diameter of the entire cluster is 5′.

2527. The diameter is 20′. The cluster contains a curious configuration like the Sickle in *Leo*.

2539. The diameter is 15′, and the brightest stars are of mag. 10.

2542. The discoverer, h, calls this a nebulous star of the fifth magnitude. I examined it on one night, and saw a faint halo about 2′ in diameter encircling it. It looked like a telescopic glare.

2571. The two brightest stars are of mag. 8·5. The mean diameter is 15′.

2580. The average diameter is 6′.

2587. This contains but one star of mag. 9. Most of the others are fainter than mag. 11.

2589. This I have searched for on three nights without success, though it is supposed to be only "p F."

2590. The star mentioned by Stephan is of mag. 13. The elongation of the nebula is at 80°.

2627. This measures 3′ north and south, and 6′ transversely. There are a few stars of mag. 11; the rest are very faint. A smaller cluster of the same general characteristics lies 5′ south.

2848. The "* 11 nf 3′" is of mag. 9·5, and follows 10 seconds, 1′·5 north.

2863 and 2869. H discovered 2863 and Müller found 2869. Their descriptions agree, but Müller's place for 2869 is erroneous. The two are identical. The two stars mentioned by each observer are of mags. 11·5 and 13 respectively; the brighter lies nearly north, and a rough sketch makes it less than 1′ distant; the other is twice as far away to the south. 2863 follows 2868 9 seconds, 0′3 south.

2868. The position is $9^h\ 18^m\ 35^s, -10°\ 0'\cdot0$.

2890. The position is $9^h\ 21^m\ 44^s, -14°\ 5'\cdot8$.

2983. A star of mag. 14 precedes 2 seconds, a trifle north.

2996. I cannot see any nebula in the N.G.C. place, though the description of h is only "v F." But 33 seconds following it, at nearly the same declination, is a nebula corresponding to h's description, except in one particular. The N.G.C. states "* 20 f 1′," while I find a star of mag. 9 which follows the nebula 4 seconds, 0′·3 north. The centre of the nebula is of mag. 13. Its position is $9^h\ 41^m\ 52^s, -21°\ 6'\cdot6$.

3085. This is called "R" by h, but it seems to be much elongated at 90°.

3103. According to the N.G.C. this nebula lies between 3100 and 3108, at nearly the same declination. I find no nebula there; by a study of Swift's original record, a

copy of which he kindly sent, it becomes practically certain that he saw 3100, but did not take its place with sufficient accuracy. Therefore 3103 does not exist.

3208. This extremely faint nebula is 1′ in diameter, and lies half way between two stars of mag. 10·5 on nearly the same parallel. A rough sketch makes it 2′ distant from each star. Its position is $10^h\ 15^m\ 2^s, -25°\ 18'·9$.

3233. The position is $10^h\ 17^m\ 12^s, -21°\ 45'·8$.

3313. This is a nebulous star of mag. 12. The "∗ 15 n 3″" is really south of the nebula. The position of the nebula is $10^h\ 32^m\ 41^s, -24°\ 47'·8$.

3331. The position is $10^h\ 35^m\ 22^s, -23°\ 17'·9$.

3369. The position is $10^h\ 41^m\ 58^s, -24°\ 43'·0$.

3420. The position is $10^h\ 45^m\ 15^s, -16°\ 42'·7$.

3464. This has an excentric faint nucleus and is much elongated at 135°. It position is $10^h\ 49^m\ 48^s, -20°\ 32'·0$.

3479. The position is $10^h\ 53^m\ 57^s, -14°\ 25'·5$.

3508. Of this the N.G.C. remarks, "∗ nf inv." I see only a star of mag. 12, 30″ or 40″ distant at 20°. H noted the nebula as "S," with which my estimate of its size agrees; h called it "v L," and probably thought that the star just mentioned lay within the outlying nebulosity.

3717. This "m E" object is remarkable in that it looks like a comet with a bright head.

3727. The "∗ 11 sf 1′" is of mag. 12, and follows 5 seconds, 0′·7 south. The position of the nebula is $11^h\ 28^m\ 38^s, -13°\ 19'·5$.

4024. The position is $11^h\ 53^m\ 25^s, -17°\ 47'·3$.

4188. The position is $12^h\ 8^m\ 59^s, -12°\ 1'·7$.

4201. The position is $12^h\ 9^m\ 33^s, -11°\ 1'·6$.

4680. The discoverer said "1 or 2 st inv." I did not see any, but a star of mag. 11 follows the nebula 1 second, 0′·1 south.

4700. The "B ∗ p" is of mag. 10 and precedes 9 seconds, 0′·1 north. The nebula is nearly 2′ in length and very narrow. At times there seemed to be 3 or 4 minute condensations.

4802. This was searched for in vain on one night. Its description is so similar to that of 4804 that they may be identical, if the declination of 4802 is just 1° in error.

4862. Another was suspected perhaps 5′ south of this one. The position of 4862 is $12^h\ 54^m\ 15^s, -13°\ 35'·5$.

5051. The position is $13^h\ 10^m\ 50^s, -27°\ 45'·4$.

5072. This nebula of d'Arrest's I observed in moonlight, when it looked almost like a double star of mags. 12–13, angle 30°, and distance 15″. The "∗14 nf" is of mag. 11·5, and follows 7 seconds, 0′·7 north.

5097. This appears to be elongated at 45°. The discoverer

says "nearly bet. 2 st." The stars are of mags. 9·5 and 11. The brighter of them follows the nebula 9 seconds, 0′·8 north. The fainter is about twice as far away.

5291. The "$\overset{*}{*}$ p" is of mags. 9·5 and 10, and wide, with an angle of 200°. The brighter star precedes the nebula 9 seconds, 0′·9 north.

5304. The "v F * f" is at 160°, 0′·7 distant, and is of mag. 12. The position of the nebula is $13^h\ 44^m\ 19^s$, $-30°\ 4'·9$.

5425. The nebula is much elongated at 290°. The position is $13^h\ 56^m\ 57^s$, $+48°\ 55'·6$.

5439. The elongation is at 0°. The position is $13^h\ 58^m\ 1^s$, $+46°\ 47'·7$.

5459. The "p B * sp" is of mag. 10·5, and precedes 6 seconds, 1′·4 south.

5495. The "* sf" is of mag. 10, and follows 2 seconds, 0′·4 north.

5597. There is a good nucleus of mag. 12·5.

5624. The position is $14^h\ 23^m\ 9^s$, $+52°\ 2'·1$.

5664. Two or three other very faint nebulæ are suspected near by. The position of 5664 is $14^h\ 28^m\ 15^s$, $-14°\ 10'·8$.

5707. The N.G.C. description is "B, pS, R." This is correct for the central portion of the nebula. But there appear to be two extremely faint and opposite extensions, which bring to mind certain drawings of the solar corona.

5734 and 5743. The discoverer puts these a minute apart in right ascension, and gives them the same declination. I find two nebulæ at nearly the same right ascension, which differ 2′·6 in declination, and see nothing else in the neighbourhood; 5743 is much elongated at 90°. I make 5734 brighter than 5743, while the discoverer has it fainter. It is possible that Leavenworth did not notice the nebular character of one of the objects which I saw (as it is very small, and has a stellar nucleus of mag. 13), and either saw something which I missed, or saw 5743 on two different nights, recording it as two objects because of the differing positions obtained for it. Yet it seems preferable to assume that we observed the same objects, and that the preceding one of the two should be called 5734. Possibly a larger telescope will be needed for a definite decision. The positions are :—

			h m s	° ′
5734	...	...	14 39 29,	− 20 26·9.
5743	...	...	14 39 31,	− 20 29·5.

5762. The position is $14^h\ 43^m\ 55^s$, $+ 12°\ 52'·4$.

5763. The position is $14^h\ 44^m\ 11^s$, $+ 12°\ 54'·4$.

5766. The position is $14^h\ 47^m\ 26^s$, $- 20°\ 58'·3$.

5781. The "* 16 s p" I did not see. But there are two stars of mag. 12 close by the nebula, south, preceding and following respectively.

5793. The elongation is at 160°. The position is $14^h\ 53^m\ 50^s,\ -\ 16°\ 17'\cdot6$.

5801. The position is $14^h\ 54^m\ 56^s,\ -\ 13°\ 30'\cdot5$.

5802. The position is $14^h\ 55^m\ 0^s,\ -\ 13°\ 31'\cdot4$.

5803. The position is $14^h\ 55^m\ 4^s,\ -\ 13°\ 29'\cdot9$.

5810. The nebula lies "bet. 2 v F st" which are of mag. 13·5 and are distant from the nebula about $0'\cdot7$, nearly north and south respectively. The position of the nebula is $14^h\ 57^m\ 5^s,\ -\ 17°\ 28'\cdot5$.

5815. I could not find any nebula in the N.G.C. place for this, but 100 seconds preceding was a nebula which answered the description of 5815, except that I saw no "D * inv." But the seeing was not very good. The position is $14^h\ 54^m\ 54^s,\ -\ 16°\ 26'\cdot1$.

5817. The position is $14^h\ 54^m\ 7^s,\ -\ 15°\ 46'\cdot9$.

5855. The "2 st n f" are of mags. 10·5 and 13. The brighter follows the nebula 3 seconds, $1'\cdot3$ north.

5878. The centre is of mag. 12.

5978. The position is $15^h\ 36^m\ 54^s,\ -\ 12°\ 54'\cdot8$.

6080. This is accompanied by a star of mag. 12·5, 20″ distant at 45°, which appeared to be nebulous

6168. The "F * at p end" I did not see. The position of the nebula is $16^h\ 25^m\ 32^s\ +\ 20°\ 27'\cdot1$.

6225. The N.G.C. says "F st inv." These I did not see, but there is a star of mag. 13 which follows 1 second, a little south.

6335. This is described by L as "Dif. neb. in patches." On one good night this was carefully sought, both with the twenty-inch, and with its five-inch finder. Nothing was discerned except possibly a very diffuse and extremely large nebulous region.

6356. In the N.G.C. this is described as a globular cluster of stars, "vB, c L, vgvmbM, r r r, st 20." It was very carefully examined on one night when the seeing was fine, but no stellar character could be made out. The longer one looked the more probable it seemed that the object was a nebula. The brilliant part of it is 30″ in diameter, the brightest spot being a little south of the centre of this brilliant portion. A number of 14 mag. stars were close to the nebula, south preceding.

6360. For this h notes "Neb in patches (Milky Way)." On one good night nothing definite was discernible here. However, the general background of the sky in this region was noted as being not so dark as would be expected if no nebulous matter were present.

6450. On each of three nights I hunted unsuccessfully for this; from its description it should not be difficult.

6562. The position is $18^h\ 3^m\ 13^s$, $+ 56°\ 15'\cdot2$.

6582. A star of mag. 13·5 precedes about 2 seconds. The position of the nebula is $18^h\ 8^m\ 37^s$, $+ 49°\ 53'\cdot0$.

6585. The elongation is at 45°, the nebula being 1'·0 or more in length, and brighter in the middle. It appeared to have a backbone or central stripe of greater brightness than the rest. The position is $18^h\ 9^m\ 5^s$, $+ 39°\ 36'\cdot3$.

6592. The position is $18^h\ 8^m\ 48^s$, $+ 61°\ 23'\cdot9$.

6597. The "B * nr" is of mag. 8·5, and precedes the nebula 25 seconds, 0'·3 north.

6601. The position is $18^h\ 10^m\ 43^s$, $+ 61°\ 25'\cdot6$.

6607. On three nights this was looked for without success. On one of the nights, which was fine, I suspected one or two objects in the immediate vicinity, but could not be certain. As it is "v. diffic." a larger telescope might well be tried on it.

6608 and 6609. A nebula supposed to be 6609 was measured in two nights. Its position differs from that given by Swift only 16 seconds in right ascension, and 0'·4 in declination. The "F * nr" is of mag. 12, and lies about 25" south of the nebula, a little preceding. There is another star of mag. 13·5 which is on the opposite side of the nebula, at about the same distance. 6608 is supposed to precede 6609 by 5 seconds at the same declination, but I could not find it on any one of three nights, one of which was very fine. I presume that it is identical with 6609. The position is $18^h\ 11^m\ 30^s$, $+ 61°\ 18'\cdot2$.

6612. I was unable to find anything in the N.G.C. position for this "v. diffic." object, but I measured a supposed nebula about 5' away, making at the time of observation the following note "e F, e S; a little question whether there really is nebulosity here." Possibly 6612 is identical with (1279), with an error of 5 minutes in right ascension. The position of the measured nebula is $18^h\ 12^m\ 41^s$, $+ 36°\ 2'\cdot5$.

6617. The position is $18^h\ 13^m\ 2^s$, $+ 61°\ 17'\cdot0$.

6621 and 6622. In the N.G.C. these have the same right ascension. One precedes the other several seconds. I retain the number 6622 for the northern one of the two; it appears to be a star of mag. 12·5, with a faint formless surrounding nebulosity. 6621 seems to be a star of mag. 13, with a shred of nebulous matter clinging to it. The positions are:

			h m s	° '
6622	...	...	18 13 24,	+ 68 19·9.
6621	...	...	18 13 28,	+ 68 19·3.

6636. The three stars mentioned by Swift are of mags. 9, 9·5, and 10·5. The one of mag. 9·5 follows the nebula 4 seconds, 1'·0 south. The others precede, and are also south.

6645. This is composed of scattered faint stars, is about 10′ in diameter, and has in its centre a nearly circular "hole," 2′ in diameter, in which only a few tiny stars are visible.

6646. In hunting for (1288) I came across this nebula, and noted that it contained a good condensation of mag. 13.

6647. Here is simply a region where small stars are a little more crowded than commonly. It seems hardly sufficiently condensed to be called a cluster.

6649. This is a widely scattered cluster about 5′ in diameter. The brightest star is of mag. 9, and is at the southern end of the cluster; it has a companion of mag. 11 at 90°, 5″ distant.

6651. The position is $18^h\ 25^m\ 52^s$, $+71°\ 32'{\cdot}4$.

6666. An unsuccessful search for this was prosecuted on two nights. As it is called "v. diffic.," the region may well be examined with a larger telescope. Swift writes that this was discovered by his son, and that its position may not be very exact.

6667. The double-star mentioned by Swift is of mags. 11—11, and distance 40″; it follows the nebula several seconds. The elongation is at 90°±. The position of the nebula is $18^h\ 31^m\ 0^s$, $+67°\ 54'{\cdot}7$.

6668. This is called "pB, pS, mE" by its discoverer, and therefore ought to be an easy object. I have searched for it on three nights unsuccessfully, and conclude that no such nebula exists in or near the place given for it. It may be identical with 6677, which follows about 3^m at nearly the same declination.

6676. The position is $18^h\ 33^m\ 15^s$, $+66°\ 52'{\cdot}7$.

6677. The N.G.C. says: "bet. * v close and v FD *." I did not notice the very faint double star; the other one is of mag. 12, and follows the nebula 2^s, 10″ south. The position of the nebula is $18^h\ 33^m\ 42^s$, $+67°\ 1'{\cdot}7$.

6678. Though this is only "pF, pS," I was unable to find it on either one of two nights. Its presumably fainter neighbours 6677 and 6679 were measured.

6679. This is a nebulous double star of mags. 12·5, distance 5″, and angle 60°. The N.G.C. place is 8′·5 out in declination. The position is $18^h\ 33^m\ 37^s$, $+67°\ 3'{\cdot}3$.

6687. The position is $18^h\ 36^m\ 1^s$, $+59°\ 33'{\cdot}2$.

6690. This is given as "R" in the N.G.C. But it really has two faint wings stretching out north and south from the much brighter centre, making the nebula 1′·5 long. At its northern end is a star of mag. 12.

6691. For this the N.G.C. gives the note "pB * Snr," which is evidently intended for "pB * snr." The star is of mag. 9·5, and is 3′·0 distant.

6696. The N.G.C. place is 1^m out in right ascension and 2′ in declination. The nebula is elongated north and south,

and is a difficult object. The position is $18^h\ 38^m\ 39^s$, $+59°\ 14'·3$.

6701. The elongation is very pronounced, and is at 120°, the nebula pointing at a star of mag. 10, less than 1′ distant. There is one condensation of mag. 13; one of mag. 14 was suspected at the preceding end of the nebula.

6714. On three nights this was looked for unsuccessfully. Upon each of them there was noticed a group of four stars of mag. 14, about 1^m following the N.G.C. place of 6714, and near "sev B st," as noted by the discoverer. On one night of the three an extremely faint nebula was suspected close to the N.G.C. place of 6714. A larger telescope or keener eye may be needed to clear this matter up.

6732. This is star-like, and of mag. 12·5. The "F*nr" is of mag. 11, and precedes 1^s, 0′·6 north. The position of the nebula is $18^h\ 54^m\ 5^s$, $+52°\ 14'·7$.

6747. On two nights this was searched for in vain. Swift says "p B st sf." I saw a star of mag. 8·5 in the vicinity, and only very faint stars in the location of the nebula. As Swift calls it "ee F v. diffic.," a larger telescope may well examine the region.

6757. Swift says "3 F st inv." I was unable to verify this, but saw two stars of mag. 12 close south preceding. The position is $19^h\ 3^m\ 7^s$, $+55°\ 33'·8$.

6759. The "v FD* close sp" noted by Swift, is of mags. 11·5—12·5, and distance 15″. I think that there are involved in the nebula three stars of mags. 13·5, 14, and 14.

6762 and 6763. These are identical; Swift admits it. The region was scrutinised on one night, the definition being fine. A star of mag. 13 follows the nebula 1^s, a few seconds of arc south. It is doubtless the star referred to in the description of 6763, and does not appear to be nebulous. The position is $19^h\ 4^m\ 51^s$, $+63°\ 46'·7$.

6764. The elongation is north and south. Four stars of mag. 13·5 are involved, one near each end, and the others in the middle.

6786. The "2 st n f" are of mag. 10. The nearer one follows 11^s, 1′·0 north. The more distant is very nearly north of the nebula, at a distance of about 2′. The N.G.C. description is "e e F," but the nebula appears to be only "F."

6787. The "4 st s f" are of mag. 10·5, form a rude square, and are judged by a rough sketch to be 5′ distant from the nebula. The position is $19^h\ 14^m\ 45^s$, $+60°\ 14'·3$.

6796. This is very much elongated at 0°, and certainly contains one bright spot of mag. 13·5; perhaps there are others. There is a resemblance to the great nebula in *Andromeda*. The position is $19^h\ 20^m\ 10^s$, $+60°\ 57'·3$.

6801. This contains at least one stellar point of mag. 13·5.

The "F * s nr" is of mag. 11·5, and precedes the nebula 3^s, 1'·3 south.

6817. The position is $19^h\ 36^m\ 8^s$, $+62°\ 9'·4$.

6825. The "F*nr" is of mag. 10, and precedes the nebula 3^s, 0'·5 north. Two stars of mags. 8·5 and 9 are about 5' south following. The position is $19^h\ 40^m\ 54^s$, $+63°\ 50'·1$.

6829. The "p B*" mentioned by Swift is of mag. 9, is 0'·7 south of the nebula, and follows 2^s. The position is $19^h\ 45^m\ 25^s$, $+59°\ 39'·5$.

6831. The position is $19^h\ 46^m\ 15^s$, $+59°\ 38'·5$.

6869. The position is $19^h\ 59^m\ 56^s$, $+65°\ 56'·9$.

6907. By my sketch this is much elongated at 90°. The centre is as bright as a star of mag. 13. The "3 st p," mentioned in the N.G.C., do not appear in my sketch, and are therefore probably more than 5' away.

6916. The "F* close p" is of mag. 12, and the position of the nebula is $20^h\ 21^m\ 21^s$, $+58°\ 1'·3$.

6927, 6928, 6930, (1325) and (1326). On page 137 of my communication in *Monthly Notices*, vol. lx., No. 2, the opinion was expressed that (1325) and (1326) were identical with 6928 and 6930 respectively. But the fact that I had not noticed the much fainter object 6927, which was in the same field of view, threw some doubt upon my conclusions. But on the evening of 1899 October 6, I measured the positions of objects which are in the places given in the N.G.C. for 6927, 6928, and 6930. The seeing was good, the stars being bright and quiet. (1326) must be identical with 6930, because their positions and descriptions, as given by Swift and Marth respectively, agree well enough with each other and with my description of the same object. The elongation noted by all of us is at 180°. The "p F*s" mentioned by Swift is of mag. 10, is 0'·9 south of the nebula, and precedes it $1·4^s$. 6928 is the brightest of the three, and my position of it agrees with Marth's. Swift's position for (1325) agrees exactly in right ascension with Marth's for 6928, but differs 3'·0 in declination. I am confident that no nebula answering to the description of (1325) exists in the N.G.C. place of that object. 6927 is extremely faint and extremely small, looking like a star of mag. 13, with but a trace of outstanding nebulosity. South and a little preceding 6927 is a row of four small stars, 1'·5 long, pointing at the nebula; the nearest star is only 2' from it. Possibly this line of stars is a trifle nebulous. The positions are :—

		h m s	° '
6927	... ...	20 27 49,	+9 34·6
6928	... ...	20 28 1,	+9 35·2
6930	... ...	20 28 10,	+9 32·0

6931. Though this is very small, it is much elongated at 120°. At times it appeared to have a condensation near each extremity, but the seeing was not very good. The position is $20^h\ 28^m\ 13^s$, $-11°\ 42'\cdot5$.

6951. The position is $20^h\ 35^m\ 59^s$, $+65°\ 45'\cdot2$.

6953. I could not find this, which is called by Swift "eeF, p L, v. diffic." 17^s preceding and $0'\cdot2$ south of the place given by Swift is a small group of at least four stars of mag. 14, which was scrutinised for nebulosity, but in vain. The position of the preceding one of the stars was taken, and is $20^h\ 36^m\ 23^s$, $+65°\ 24'\cdot7$.

6981. This is a bright and easily resolvable globular cluster. But the most brilliant portion is not at the centre, but near the preceding edge.

7015. This contains a condensation of mag. 13·5.

7136. A note about this appears on p. 359 of the *Monthly Notices*, vol. lviii., No. 6. The nebula has been observed again, with the same result concerning its appearance. In the N.G.C. we read "∗9·5 f 2′." The magnitude of the star is really about 10·5.

7302. This is suitable for parallax measures, having a good condensation. A star of mag. 8·5 is about 3′ distant.

7306. The "∗11 p" appears to be of mag. 10, and precedes 8^s, $0'\cdot7$ north. The nebula seems brighter near its preceding end.

7308. This nebula would be good for parallax observations with a large telescope. Its position is $22^h\ 29^m\ 13^s$, $-13°\ 27'\cdot0$.

7437. The "F ∗ nr n f" is of mag. 10·5, and follows 4^s, $1'\cdot4$ north. The position of the nebula is $22^h\ 53^m\ 12^s$, $+13°\ 46'\cdot3$.

7455. Swift says "F∗close p." I found none there, but a star of mag. 10 follows $5\cdot5^s$, $1'\cdot2$ north.

7495. The "∗9 n f nr" is of mag. 10·5, and follows less than 1^s, $1'\cdot3$ north. There is a star of mag. 9 about 5′ south following.

7511. There is a star of mag. 13·5 about 30″ south of the nebula. The discoverer says "sev st n f." I see a row 15′ in length, composed of six stars of average mag. 10, which runs at a position angle of 135°; its centre lies about 3′ north following the nebula.

7522. A search on three nights failed to reveal this.

7573. The N.G.C. right ascension is about 50^s too large. Accurate measures were prevented by the coming up of haze.

7627. I failed to find this on two nights. In reply to a letter of inquiry, Swift says that this is identical with 7641, one of Stephan's nebulæ which I have measured. With this opinion I agree, having seen near 7641 the "2 st n" mentioned by Swift.

7720. There seems to be a small nest of nebulæ clustered about this one. I have measured two, and suspected some others. An examination with a large telescope might be fruitful. 7720 is described as "l E, b M." It looks like a nebulous double star of mags. 12–13·5, angle 10°, and distance 10″.

7754. The N.G.C. right ascension is a minute and a half too small. The position is $23^h\ 44^m\ 2^s$, $-17°\ 9'\cdot 3$.

7759. The "B*n" is of mag. 8·5, and precedes the nebula a fraction of a second, 2′·7 north. The nebula has a good nuclear brightening, and would readily lend itself to parallax observations. The position is $23^h\ 43^m\ 45^s$, $-17°\ 5'\cdot 8$.

7763. The "F*f" is of mag. 13·5, and follows about 2^s, a trifle north. The position of the nebula is $23^h\ 45^m\ 7^s$, $-17°\ 8'\cdot 7$.

7774. The N.G.C. says "in centre of 3 st." Each side of the triangle is about 4′ long, and the stars are of mags. 10, 11, and 12.

7808. The "stell. N" is of mag. 13. The "* 8·5 sp 3′" precedes 13^s, 1′·6 south. The position is $23^h\ 58^m\ 25^s$, $-11°\ 18'\cdot 1$.

7813. I do not find anything in the N.G.C. place of this Müller nebula. But 55^s following, at nearly the same declination, I found a similar object, elongated, however, at 160°, while Müller puts the elongation at 80°. He says "*8·5 f 38^s," while I found such a star preceding 49^s. He also says "*9 np 40^s." There are two such stars about 8′ north, and a few seconds preceding. The region may well be examined with a larger telescope. The position is $23^h\ 59^m\ 2^s$, $-12°\ 32'\cdot 4$.

Nebulæ from the Index Catalogue.

(81). I could find no "*close n f." A star of mag. 11 follows 3^s, 0′·3 south. The position of the nebula is $1^h\ 4^m\ 16^s$, $-2°\ 13'\cdot 8$.

(179). The "*9·5 n f" follows 10^s, 1′·4 north. The position of the nebula is $1^h\ 54^m\ 13^s$, $+37°\ 32'\cdot 2$.

(395). The "F*close f" is of mag. 12, and follows $1\cdot 5^s$. The position of the nebula is $4^h\ 44^m\ 26^s$, $+0°\ 4'\cdot 7$.

(438) and Swift 88. These are identical, despite their differing descriptions. Swift, writing under date of 1900 January 27, says that "they are no doubt the same." The "v wide D* nr p" is of mags. 9–9·5, distance 45″, and angle 170°. The brighter of the two stars precedes the nebula 15^s, 0′·7 north. I have discovered another fainter nebula, which precedes 24^s, 5′·4 north.

(453). On the fine night on which I measured (452) I looked for this one in vain. In its place I could see only two or

three stars of mags. 13–14. Bigourdan, the discoverer, says "* 13 in S neb, or 2 or 3 st close."

(468). I hunted for this on two fine nights unsuccessfully. There are hosts of stars in the vicinity. The place is near that of the large nebula 2359.

(507). A search for this on three nights has failed.

(760). Either there is a star of mag. 14 at 150°, or the nebula is elongated in that direction.

(784). The "p B * s" is of mag. 8·5, and precedes $0^s.6$, $2'.9$ south. The N.G.C. declination is several minutes of arc out. The elongation of the nebula is at 90°, and its position is $12^h\ 17^m\ 22^s$, $-4°\ 5'.9$.

(847). The description "bet. 2 st" given in the *Index Catalogue*, I cannot verify from my sketch of the field of view.

(852). Corresponding to the description "B * p" I find one of mag. 9, which precedes about 3′, by a rough sketch, and is a little north. The position of the nebula is $13^h\ 3^m\ 37^s$, $+60°\ 41'.5$.

(997), (998), Swift 168, and Swift 169. I have examined this locality with considerable care, and see three nebulæ, one of which is evidently a *Nova*, as its description is widely different from that of any of the others. (997) and Swift 168 agree in description, and are thought to be identical. The "* with dist. comp. nr n" is of mag. 9·5, and follows the nebula less than 1^s, $1'.3$ north. Its companion is of mag. 10·5, and is 40″ distant from the brighter star, at an angle of 225°. (998) is very much fainter and smaller than (997), and is judged to be identical with Swift 169. Near it is a star of mag. 14, at an angle of 180° and distance of 20″. Perhaps it is involved in the faint outlying nebulosity. It is to be noticed that, according to the *Index Catalogue* (998) follows (997) 18^s, $1'.0$ north, these differences of coordinates being identical with those obtained from *A.N.* 3517, for Swift 168 and 169. The positions of the three nebulæ are :—

	h	m	s	°	′
Nova	14	14	12,	−4	1·6
(997)	14	14	47,	−3	59·5
(998)	14	15	7,	−3	57·4

(1027). Swift suspected "another nr." I saw no nebula near by, but there was a star of mag. 13, which was $0'.7$ south preceding.

(1031). The position is $14^h\ 30^m\ 50^s$, $+48°\ 28'.5$.

(1071). The position is $14^h\ 49^m\ 13^s$, $+5°\ 9'.5$.

(1101). The *Index Catalogue* gives no description of this. I find it to be extremely faint and very small. A star of mag. 13 follows $1^s.5$, at nearly the same declination, and another precedes 2^s, a little north.

(1121). The "v F * close p" is of mag. 13·5, and is 20″ distant at 315°.

(1149) and Swift 182. These are identical. The "trapezium," mentioned by the discoverer, is nearly a rhomboid, whose longer diagonal is about 8′ in length, by a rough sketch, and stands at a position angle of 135°; the shorter diagonal is about 4′ long. The stars are of mags. 9·5, 10·5, 10·5, and 11·5, the brightest being in the southern end of the long diagonal. The position of the nebula is $15^h\ 53^m\ 26^s$, $+12°\ 21'·4$.

(1196). Of this the *Index Catalogue* says "nr p * of 3 in line." It is somewhat difficult to determine which stars are referred to. The brightest star near by is of mag. 8·5, and follows the nebula 8^s, 1′·3 south.

(1247). On two nights this was hunted for in vain. On the second night, when the seeing was fine, it was noted that there is a star of mag. 13 in the place given, which satisfies the description "* 9·8 sp 0′·7," but no trace of nebulosity was discernible about the star.

(1268). The position is $17^h\ 46^m\ 13^s$, $+17°\ 14'·3$.

(1269). As the position given in the *Index Catalogue* differs from mine 20^s and 2′, and I was unable to verify Swift's description of "p L, 2 F st nr," I examined the locality with care, under excellent atmospheric conditions. But I found only the following "eeF, vS" nebula, which is assumed to be (1269). A number of faint stars lie near, most of them being south of the nebula. Perhaps there are a dozen brighter than mag. 13 within a distance of 5′. The brightest one is of mag. 10, and is (judging by a rough sketch), about 4′ south preceding the nebula. No other brighter than mag. 11·5 is shown in the sketch.

The position is $17^h\ 47^m\ 52^s$, $+21°\ 35'·6$.

(1279) and (1281). In the *Index Catalogue* is a query whether these are identical. Their descriptions are not radically divergent. I see only one nebula in the vicinity, and call it "v F, p S." Within 5′ north following are four stars of mag. 9; 11^s following and 1′·0 south is a double of mags. 9·5 – 10, and distance 3″.

The position is $18^h\ 7^m\ 45^s$, $+35°\ 59'·0$.

(1288). The discoverer mentions "3 st nr." They are of mag. 10, and form a triangle within which the nebula lies, near the middle of the south following side. The triangle lies about 5′ south of a star of mag. 8·5, and follows it a few seconds.

(1289). The stars referred to in the description "3 st nr" probably are the ones constituting a triangle each side of which is about 5′ long, which lies south of the nebula. The vertices nearest the nebula are marked by stars of mag. 10 and 10·5, which have nearly the same declination. The third vertex is marked by a star of mag. 8·5, which is nearly due south of the nebula, distant about 7′.

The position of the nebula is $18^h\ 26^m\ 46^s$, $+39°\ 53'.7$.

(1291). The discoverer mentions a "F * close n." This I am unable to see. Two stars of mag. 12 lie north following and north preceding, respectively. North following the nebula, at a greater distance lie two of mag. 10, which point at it. They are (by a rough sketch) 1′ or 2′ apart. The nearer one precedes the nebula 8^s, $2'.3$ north.

The position is $18^h\ 31^m\ 19^s$, $+49°\ 11'.8$.

(1293). Swift describes this as "eeF, S, lE, * in centre, ? D." It appears to consist of three stars of mag. 14, of which the following one is nebulous.

(1300) and (1301). On each of two nights I searched for these in vain. A letter from Swift states that the N.P.D. given for (1300) in the *Index Catalogue* is 1° too great. Making this correction (1300) becomes identical with 6798. In the same letter Swift states that the declination of (1301) is about +49° 40′, which is 35′ greater than the declination (for 1900·0) computed from the *Index Catalogue.*

(1368). This is called "R" by its discoverer. On each of two nights I noted it as much elongated at 225°. On one of the nights it appeared to contain two stellar points, one near each end.

(1420). The position is $21^h\ 57^m\ 48^s$, $+19°\ 16'.1$.

(1487). The "F * nf" is of mag. 12, and is close to the nebula. There is also a star of mag. 11·5 at about the same distance south preceding. The "* 8 f" must be a long way off, as I saw no such star in the vicinity. There is a star of mag. 7, which precedes about 15 seconds, $9'.2$ south.

Swift's Recently Discovered Nebulæ.

Swift 12, 3. On p. 568 of *Monthly Notices*, vol. lix. No. 10, the discoverer says that a "wide D * close p point to it." The magnitudes of the components of the double are 9·5 and 12, and by a rough sketch I judge their distance apart to be 1′ or 2′. The star of mag. 9·5 precedes the nebula 8 seconds, $0'.1$ north. A star of mag. 13 is close to the nebula, south following.

Swift 10. The "9^m * nearly in contact np" precedes 0·5 second, $0'.5$ north, and I rated it as of mag. 10. The position of the nebula is $0^h\ 56^m\ 44^s$, $-16°\ 6'.3$.

Swift 26. The position is $1^h\ 46^m\ 11^s$, $-10°\ 17'.2$.

Swift 28. The "9^m nr np" precedes 7 seconds, $1'.6$ north. The position of the nebula is $1^h\ 51^m\ 8^s$, $+5°\ 8'.3$.

Swift 32. Swift says "bet. 2 southern of 4 stars." The stars are of mag. 10·5, and form a large trapezoid, the southern and longest side of which is about 7′ in length, and stands at a position angle of 60°.

Swift 43. The position is $2^h\ 37^m\ 18^s$, $-28°\ 35'.8$.

Swift 60. I have not yet observed this, but it may be

identical with one which was observed by Müller in 1887, but which is not found in the *Index Catalogue*, or in the N.G.C. The observation of it is No. 171 on pp. 192–3 of Part 6 of vol. I. of the *Publications of the Leander McCormick Observatory*. Its position for 1900·0 is $3^h\ 37^m\ 15^s$, $-18°\ 35'·2$, which differs from that of Swift 60 by 14 seconds in right ascension, and $2'·9$ in declination. It is also noteworthy that if the sign of $\Delta\alpha$ in Müller's observation be changed, the position of his nebula will coincide with that of 1440. The region $3^h\ 33^m$ to $3^h\ 43^m$ between the declinations $-18°\ 30'$ and $-19°\ 0'$ might well be explored thoroughly with a large telescope, as it contains many nebulæ.

Swift 74. Swift's declination for this is nearly 10′ in error. He says "close to e e e FD ∗." The double is of mags. 12·5—12·5, distance 90″, and angle 210°. The nebula is near the northern one of the two stars. The position of the nebula is $5^h\ 2^m\ 32^s$, $-20°\ 28'·6$.

Swift 75. The discoverer says "7^m ∗ 15^s p l s" nearly obliterates it. The star precedes 14 seconds, $3'·6$ south. The position of the nebula is $5^h\ 15^m\ 39^s$, $-25°\ 10'·0$.

Swift 85. The elongation is at 90°. The position is $5^h\ 42^m\ 30^s$, $-18°\ 45'·7$.

Swift 96. Of this Swift says "vF ∗ close nf, pB ∗ near sp." The very faint star is of mag. 12·5, and is distant 40″ at 10°. The brighter star is of mag. 9, precedes the nebula 6 seconds, and is $2'·4$ north instead of south. The position of the nebula is $9^h\ 40^m\ 14^s$, $-31°\ 19'·9$.

Swift 106. The trapezium mentioned by Swift consists of stars of mag. 9·5. The position of the nebula is $10^h\ 11^m\ 51^s$, $-33°\ 2'·8$.

Swift 107. The "9^m p close f" follows the nebula 9 seconds, $0'·4$ south. Nearly between the two is a star of mag. 10·5. There is also a star of mag. 12·5, which follows 40″, at 80°. The nebula has a good nucleus of mag. 13. Its position is $10^h\ 17^m\ 6^s$, $-33°\ 45'·8$.

Swift 108. 3257, 3258, and 3260 are in the same field, and I measured them all on the same night, but could not see Swift 108, which is supposed to be close by. 3260 has a star of mag. 11·5 about 20″ south, and Swift 108 is said to have an "e F ∗ in contact." Since the position and description of Swift 108 agree closely with those of 3260, I judge them to be identical.

Swift 111. The "8^m ∗ close p" is of mag. 9, and precedes 4 seconds, $0'·2$ north. The description "eE" may have arisen from the fact that there is a star of mag. 13 close by, south following.

Swift 115 and 116. Swift says in a letter that these are to be dropped. The former is evidently identical with the

h nebula 3333. The "* 15 att" is of mag. 13, and directly south of the nebula.

Swift 120. This has a stellar nucleus of mag. 13·5.

Swift 130. There is no nebula in the place given for this, but about 15′ away there is one corresponding to the description, and answering the condition "7^m * sp." Its position is $11^h\ 50^m\ 11^s$, $-37°\ 8'{\cdot}4$.

Swift 131 and 133. These were discovered on different nights; their positions agree closely, and their descriptions fairly. I examined the locality on two nights, and found only one nebula, which is elongated at 120°, is about 1′·5 long, and points toward a star of mag. 9, which follows 15 or 20 seconds.

Swift 132. This must be identical with 4087, since both are pretty bright, and their places agree within three seconds in right ascension and 1′ in declination. The "triple * sp" mentioned by Swift is of mags. 10, 12, and 12; the brightest component precedes the nebula 8 seconds, 3′·9 north.

Swift 134. The "D * sf" is of mags. 10–10·5, angle 45°, and distance 40″; it is 8′ from the nebula. Just south of the nebula, and pointing at it is a row of five stars of average mag. 11′·5, the farthest being less than 10′ away. The nebula is considerably brighter than the description "e e e F, v diff." would imply.

Swift 135. The "* close sf" is of mag. 10·5, and follows 2 seconds, 0′·6 south. The position of the nebula is $12^h\ 3^m\ 51^s$, $-30°\ 57'{\cdot}7$.

Swift 137. The position is $12^h\ 19^m\ 51^s$, $-39°\ 13'{\cdot}2$.

Swift 139. I see no "7^m * nr p," but found one of mag. 8·5, which precedes 15 seconds, 1′·5 south. The position of the nebula is $12^h\ 22^m\ 19^s$, $-38°\ 47'{\cdot}0$.

Swift 140. Instead of "2 or 3 vF st in contact," I noticed only one of mag. 12·5, south and a little preceding. The position of the nebula is $12^h\ 35^m\ 30^s$, $-36°\ 12'{\cdot}4$.

Swift 145. This is larger and much brighter than the description "e e e F, e e e S" implies. The nearest of the "3 vF st n" is of mag. 10, and precedes 5 seconds, 1′·0 north. The "7^m * s" is 10′ distant. The position of the nebula is $12^h\ 52^m\ 50^s$, $-22°\ 20'{\cdot}1$.

Swift 149. The "11^m * nr p" is of mag. 12, and precedes 11 seconds, 0′·3 north.

Swift 150. The position is $13^h\ 2^m\ 41^s$, $-23°\ 15'{\cdot}7$.

Swift 158. There is an error of about 7′ in the declination given in *A. N.* 3517, the nebula being north of the position there given.

Swift 159. Of this the discoverer says "like a D *, one nebulous." I cannot perceive this appearance.

Swift 183. I have searched for this in vain on two nights.

As it is called "e e e F" perhaps a larger telescope may well look for it.

Swift 197 and 198. The announced positions put these at the same declination, and make them differ only 15 seconds in right ascension. They were discovered on the same night. 197 is called "v F, R," and 198 "ee F, eE." I examined the locality on three nights, and could find only one nebula which is 1′ in length, and elongated at 160°; on one night it was suspected of being binuclear. Swift says of 197 "2 F st near nf point to it," and of 198 "near p * of sev. curved." Both these statements are true of the nebula which I observed. On two of the three nights I also measured Swift 199, which is in the same field of view, was discovered on the same night, and is described by Swift as fainter than 197 and 198. Swift has sent me a copy of his original records, which says of 198 "sp of 2," and of 199 "nf of 2." For 197 there is no such remark. I conclude that there is no nebula corresponding to the position and description of Swift 197. The position of Swift 198 is $20^h\ 37^m\ 8^s, -30°\ 12'{\cdot}7$.

Swift 199. The position is $20^h\ 37^m\ 28^s, -30°\ 3'{\cdot}8$.

Swift 241. I saw nothing in the place given by Swift, but measured one 34 seconds following at nearly the same declination. It precedes a star of mag. 8, 17 seconds, $2'{\cdot}3$ south. This star has a companion of mag. 12 at 70°, 6″. The position of the nebula is $23^h\ 46^m\ 26^s, -28°\ 55'{\cdot}2$.

Note on the Total Eclipse of the Sun, 1900 *May* 28, *observed at Algiers.* By the Rev. C. D. P. Davies, M.A.

With regard to the time of first contact chronicled on p. 589 of vol. lx., and the supposition of Mr. Crommelin that the time noted was probably five seconds late, it will be absolutely safe to read "certainly" for "probably," unless Mr. Crommelin saw the contact before he proclaimed it, as I distinctly saw it in my guiding refractor of 2-inch aperture fully five seconds before Mr. Crommelin announced it.

Note on the Moon's Eclipse Diameter. By A. C. D. Crommelin.

The results of the total solar eclipses of 1898 and 1900 have established beyond a doubt that the value of the Moon's semi-diameter now used in the *Nautical Almanac* for eclipses and occultations gives too long a duration for totality. This value ($15' 32''\cdot65$) was deduced by Dr. L. Struve from a discussion of the occultations observed during the total lunar eclipses of 1884 and 1888.

The American ephemeris uses the value $15' 31''\cdot76$ for eclipses and occultations, and increases this by $2''\cdot5$ for meridian observations of the bright limb.

Now the American ephemeris durations of totality were very nearly correct in the above eclipses, from which it seems clear that their value of the semi-diameter is preferable to the *Nautical Almanac* one for this purpose.

Now it occurred to me recently that the reason that a value deduced from a large number of occultations does not give correct results for total eclipses is to be sought in the great irregularity of the Moon's limb. I was particularly struck with this in watching the disappearing Sun last May. Twenty seconds before totality the lunar mountains began to break the continuity of the solar crescent, and a few seconds before totality there was no semblance of a continuous crescent, only a row of bright beads and patches. I have drawn a figure representing diagrammatically on a greatly exaggerated scale these irregularities in the Moon's outline. The outer circle is drawn to embrace the highest mountains, the inner through the deepest valleys, while the middle one is drawn midway between the two. Now it seems clear that the discussion of a large number of occultations at various points of the limb would give us the diameter of this middle circle. But since we do not call the Sun totally eclipsed if any portion of it is visible through a lunar valley, the inner circle represents the effective diameter of the Moon as regards her power of totally eclipsing the Sun. The difference between the *Nautical Almanac* and American Ephemeris values only implies an extreme depth of the deepest lunar valleys below the mean level of about 5,000 feet, which is not at all an improbable amount. The course then that I should recommend is as follows: Struve's semi-diameter of the Moon should certainly be used for occultations, and it may be used for the prediction of first and fourth contacts of total eclipses; also for partial and annular eclipses, whose accurate prediction is of minor importance. But it is so important to predict the duration and boundaries of totality with all possible accuracy that I think it would be well to use the American value, or even a slightly smaller one (say $15' 31''\cdot70$) for this purpose. I think this

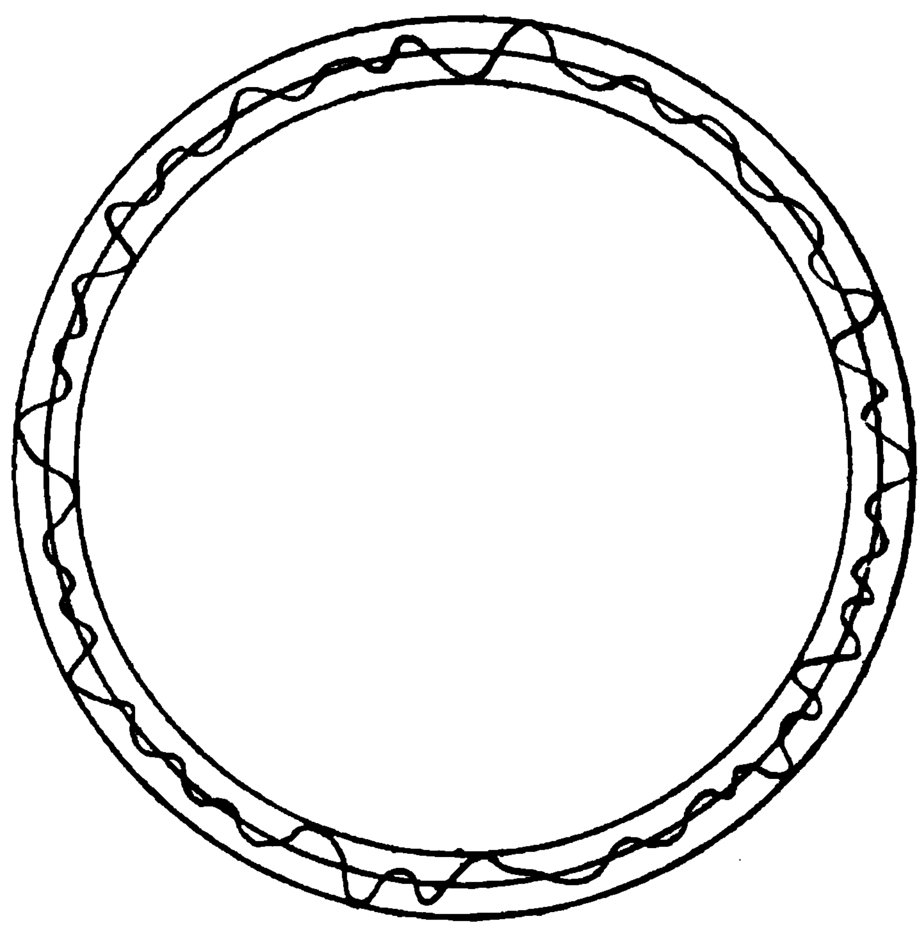
would give the duration with almost perfect accuracy ; if anything it would underestimate it, but that is on the safe side.

Curiously enough, in 1902, the American Ephemeris adopts the value 15′ 32″·55 for eclipses and occultations, and increases it by 1″·5 for meridian observations of the bright limb.

I regard this as a distinctly retrograde step as regards total eclipses, though it is probably an improvement as regards occultations.

Perhaps I may point out a small erratum in Mr. Penrose's paper in the *Monthly Notices* for April last (lx. 7, p. 483).

He says, "Compare the arguments given for the .... Moon's semi-diameter in the *Nautical Almanac* for the same day at noon .... then find from these the corrections required for the assumed time in simple proportion." He has overlooked the fact that the Moon's semi-diameter under the heading eclipses is based on Struve's semi-diameter 15′ 32″·65, while the noon and midnight values are based on Hansen's bright limb semi-diameter 15′ 34″·07. It will be near enough if the noon and midnight values are diminished by 1″·4 before proceeding to interpolate in the manner described by Mr. Penrose.



Benvenue, 55 *Ulundi Road, Blackheath, S.E.:*
1900 *October* 31.

Ephemeris for Physical Observations of the Moon for 1901.
By A. C. D. Crommelin.

Greenwich Midnight.		Selenographical Colong. of the Sun.	Lat. of the Sun.	Geocentric Libration Sel. Long. of the Earth.	Lat. of the Earth.	Combined Amount.	Direction.	C.
1901.		°	°	°	°	°	°	°
Jan.	1	48.76	+1.00	+2.82	+0.19	2.83	273.9	347.12
	2	60.89	+1.02	+3.60	+1.81	4.03	296.7	352.77
	3	73.01	+1.05	+4.23	+3.30	5.37	308.0	358.79
	4	85.14	+1.07	+4.68	+4.58	6.55	314.4	4.71
	5	97.26	+1.10	+4.87	+5.58	7.40	318.9	10.14
	6	109.39	+1.12	+4.85	+6.27	7.93	322.3	14.83
	7	121.53	+1.14	+4.50	+6.62	8.01	325.8	18.64
	8	133.66	+1.16	+3.87	+6.65	7.69	329.8	21.50
	9	145.80	+1.17	+2.96	+6.36	7.02	335.0	23.39
	10	157.95	+1.19	+1.84	+5.80	6.08	342.4	24.29
	11	170.10	+1.21	+0.56	+5.00	5.03	353.6	24.21
	12	182.26	+1.23	−0.80	+3.98	4.06	11.4	23.12
	13	194.42	+1.24	−2.15	+2.80	3.53	37.5	21.03
	14	206.59	+1.25	−3.39	+1.48	3.70	66.4	17.93
	15	218.76	+1.27	−4.43	+0.08	4.43	89.0	13.89
	16	230.94	+1.28	−5.20	−1.36	5.38	104.7	9.03
	17	243.13	+1.29	−5.63	−2.76	6.27	116.1	3.57
	18	255.31	+1.30	−5.68	−4.06	6.99	125.6	357.81
	19	267.50	+1.32	−5.34	−5.16	7.42	134.0	352.12
	20	279.69	+1.33	−4.65	−5.99	7.58	142.2	346.87
	21	291.89	+1.34	−3.68	−6.46	7.44	150.3	342.34
	22	304.07	+1.35	−2.51	−6.54	7.00	159.0	338.85
	23	316.26	+1.36	−1.26	−6.21	6.34	168.5	336.58
	24	328.44	+1.38	−0.03	−5.49	5.49	179.7	335.62
	25	340.61	+1.39	+1.10	−4.42	4.55	194.0	336.12
	26	352.78	+1.40	+2.08	−3.09	3.72	213.9	338.07
	27	4.94	+1.42	+2.90	−1.58	3.30	241.4	341.21
	28	17.09	+1.43	+3.55	0.00	3.55	270.0	345.85
	29	29.23	+1.44	+4.05	+1.56	4.34	291.1	351.21
	30	41.37	+1.45	+4.40	+3.02	5.34	304.5	357.03
	31	53.51	+1.47	+4.61	+4.30	6.30	313.0	2.89
Feb.	1	65.64	+1.48	+4.67	+5.32	7.08	318.7	8.43
	2	77.78	+1.49	+4.55	+6.05	7.57	323.1	13.35
	3	89.91	+1.50	+4.23	+6.46	7.72	326.8	17.45

Greenwich Midnight.	Selenographical Colong. of the Sun.	Selenographical Lat. of the Sun.	Geocentric Libration Sel. Long. of the Earth.	Geocentric Libration Lat. of the Earth.	Combined Amount.	Direction.	C.
1901.	°	°	°	°	°	°	°
Feb. 4	102·04	+1·50	+3·69	+6·54	7·51	330·6	20·64
5	114·18	+1·51	+2·93	+6·32	6·97	335·1	22·88
6	126·32	+1·51	+1·95	+5·80	6·12	341·4	24·13
7	138·47	+1·52	+0·78	+5·04	5·10	351·2	24·37
8	150·62	+1·52	−0·53	+4·07	4·10	7·4	23·61
9	162·77	+1·52	−1·92	+2·92	3·49	33·3	21·84
10	174·93	+1·52	−3·30	+1·64	3·68	63·6	19·10
11	187·10	+1·52	−4·58	+0·29	4·59	86·4	15·43
12	199·27	+1·52	−5·66	−1·10	5·77	101·9	10·92
13	211·45	+1·52	−6·44	−2·47	6·90	111·0	5·74
14	223·63	+1·52	−6·84	−3·75	7·80	118·7	0·15
15	235·82	+1·51	−6·79	−4·88	8·36	125·7	354·44
16	248·01	+1·51	−6·27	−5·77	8·52	132·6	348·95
17	260·20	+1·51	−5·31	−6·33	8·26	140·0	344·06
18	272·41	+1·51	−3·98	−6·51	7·63	148·6	340·06
19	284·61	+1·51	−2·37	−6·26	6·69	159·3	337·22
20	296·81	+1·51	−0·67	−5·59	5·63	173·2	335·76
21	309·00	+1·51	+0·98	−4·54	4·65	192·2	335·80
22	321·20	+1·51	+2·45	−3·20	4·03	217·4	337·39
23	333·38	+1·51	+3·67	−1·67	4·03	245·5	340·44
24	345·56	+1·51	+4·59	−0·06	4·59	269·2	344·73
25	357·74	+1·50	+5·22	+1·52	5·44	286·2	349·97
26	9·91	+1·50	+5·58	+2·98	6·33	298·1	355·71
27	22·07	+1·50	+5·70	+4·25	7·11	306·7	1·55
28	34·22	+1·49	+5·60	+5·27	7·69	313·3	7·12
Mar. 1	46·37	+1·49	+5·32	+6·01	8·02	318·5	12·13
2	58·52	+1·48	+4·87	+6·44	8·07	322·9	16·42
3	70·67	+1·48	+4·24	+6·56	7·81	327·1	19·85
4	82·82	+1·47	+3·45	+6·36	7·24	331·5	22·35
5	94·96	+1·46	+2·49	+5·87	6·38	337·0	23·89
6	107·11	+1·45	+1·36	+5·13	5·31	345·2	24·42
7	119·26	+1·43	+0·10	+4·16	4·16	358·6	23·97
8	131·42	+1·42	−1·26	+3·03	3·28	22·6	22·49
9	143·58	+1·41	−2·67	+1·76	3·20	56·6	20·03
10	155·74	+1·40	−4·06	+0·42	4·08	84·1	16·64
11	167·91	+1·38	−5·36	−0·96	5·45	100·2	12·42
12	180·09	+1·37	−6·46	−2·32	6·87	109·8	7·54
13	192·27	+1·35	−7·29	−3·60	8·13	116·3	2·17

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1901.	°	°	°	°	°	°	°
Mar. 14	204·45	+1·34	−7·73	−4·73	9·06	121·5	356·61
15	216·64	+1·32	−7·73	−5·66	9·58	126·2	351·13
16	228·85	+1·31	−7·25	−6·30	9·61	131·0	346·05
17	241·05	+1·29	−6·24	−6·59	9·07	136·6	341·67
18	253·26	+1·28	−4·79	−6·46	8·05	143·4	338·30
19	265·48	+1·27	−3·01	−5·90	6·62	153·0	336·19
20	277·70	+1·25	−1·05	−4·92	5·03	168·0	335·57
21	289·92	+1·24	+0·92	−3·58	3·70	194·4	336·57
22	302·13	+1·23	+2·74	−2·01	3·40	233·7	339·19
23	314·34	+1·21	+4·28	−0·33	4·29	265·6	343·25
24	326·55	+1·20	+5·47	+1·35	5·63	283·9	348·40
25	338·75	+1·19	+6·29	+2·89	6·92	294·7	354·20
26	350·94	+1·17	+6·72	+4·23	7·94	302·2	0·17
27	3·12	+1·16	+6·82	+5·30	8·64	307·9	5·89
28	15·30	+1·14	+6·61	+6·08	8·98	312·6	11·07
29	27·47	+1·12	+6·16	+6·54	8·99	316·7	15·52
30	39·65	+1·10	+5·47	+6·68	8·63	320·7	19·14
31	51·81	+1·08	+4·61	+6·51	7·98	324·7	21·85
April 1	63·98	+1·06	+3·58	+6·05	7·03	329·4	23·61
2	76·15	+1·04	+2·43	+5·32	5·85	335·5	24·41
3	88·31	+1·01	+1·16	+4·37	4·52	345·1	24·20
4	100·48	+0·99	−0·18	+3·23	3·24	3·2	23·00
5	112·65	+0·97	−1·59	+1·95	2·52	39·2	20·78
6	124·82	+0·94	−2·98	+0·59	3·04	78·8	17·62
7	136·99	+0·92	−4·33	−0·80	4·40	100·5	13·61
8	149·16	+0·89	−5·58	−2·17	5·99	111·3	8·92
9	161·35	+0·87	−6·64	−3·47	7·49	117·6	3·79
10	173·53	+0·84	−7·45	−4·63	8·78	121·9	358·29
11	185·72	+0·82	−7·91	−5·60	9·69	125·3	352·89
12	197·92	+0·79	−7·98	−6·30	10·17	128·3	347·79
13	210·13	+0·77	−7·60	−6·69	10·13	131·4	343·25
14	222·34	+0·75	−6·74	−6·69	9·50	134·8	339·54
15	234·56	+0·72	−5·44	−6·28	8·31	139·1	336·91
16	246·79	+0·70	−3·76	−5·44	6·61	145·4	335·62
17	259·02	+0·68	−1·82	−4·21	4·59	156·6	335·88
18	271·25	+0·66	+0·22	−2·67	2·68	184·7	337·80
19	283·49	+0·64	+2·19	−0·95	2·39	246·5	341·34
20	295·72	+0·62	+3·96	+0·83	4·05	281·8	346·23

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1901.	°	°	°	°	°	°	°
April 21	307·95	+0·60	+5·40	+2·51	5·95	294·9	352·03
22	320·17	+0·57	+6·45	+3·99	7·58	301·7	358·20
23	332·39	+0·55	+7·09	+5·19	8·78	306·2	4·22
24	344·60	+0·53	+7·31	+6·07	9·50	309·7	9·73
25	356·80	+0·50	+7·15	+6·61	9·75	312·8	14·48
26	9·01	+0·48	+6·65	+6·80	9·52	315·6	18·36
27	21·20	+0·45	+5·88	+6·68	8·91	318·6	21·32
28	33·39	+0·42	+4·88	+6·26	7·93	322·1	23·31
29	45·58	+0·40	+3·71	+5·57	6·70	326·3	24·34
30	57·76	+0·37	+2·42	+4·64	5·23	332·5	24·38
May 1	69·94	+0·34	+1·06	+3·52	3·68	343·2	23·40
2	82·12	+0·31	−0·33	+2·25	2·27	8·3	21·45
3	94·30	+0·28	−1·71	+0·88	1·92	62·8	18·51
4	106·49	+0·25	−3·04	−0·54	3·09	100·1	14·68
5	118·67	+0·22	−4·27	−1·94	4·69	114·4	10·11
6	130·85	+0·19	−5·36	−3·27	6·28	121·4	5·00
7	143·04	+0·16	−6·27	−4·46	7·69	125·4	359·62
8	155·23	+0·13	−6·94	−5·47	8·83	128·2	354·23
9	167·43	+0·10	−7·32	−6·23	9·61	130·4	349·09
10	179·64	+0·07	−7·37	−6·69	9·95	132·2	344·47
11	191·85	+0·04	−7·06	−6·80	9·80	133·9	340·59
12	204·06	+0·02	−6·37	−6·52	9·11	135·7	337·68
13	216·29	−0·01	−5·30	−5·84	7·88	137·8	335·92
14	228·52	−0·03	−3·90	−4·77	6·16	140·7	335·55
15	240·75	−0·06	−2·22	−3·37	4·04	146·6	336·73
16	253·00	−0·08	−0·40	−1·71	1·76	166·8	339·53
17	265·25	−0·10	+1·46	+0·07	1·46	272·7	343·86
18	277·50	−0·12	+3·20	+1·83	3·69	299·8	349·40
19	289·74	−0·15	+4·73	+3·45	5·85	306·1	355·49
20	301·98	−0·17	+5·91	+4·80	7·62	309·1	1·91
21	314·22	−0·19	+6·70	+5·83	8·88	311·0	7·82
22	326·45	−0·22	+7·06	+6·50	9·59	312·6	13·00
23	338·68	−0·24	+7·00	+6·80	9·76	314·2	17·28
24	350·90	−0·27	+6·56	+6·76	9·41	315·9	20·59
25	3·12	−0·30	+5·79	+6·40	8·63	317·9	22·89
26	15·33	−0·33	+4·75	+5·77	7·48	320·5	24·19
27	27·54	−0·35	+3·51	+4·89	6·02	324·3	24·49
28	39·74	−0·38	+2·17	+3·81	4·39	330·3	23·79

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1901.		°	°	°	°	°	°	°
May	29	51·94	−0·41	+0·78	+2·57	2·69	343·1	22·08
	30	64·13	−0·44	−0·61	+1·22	1·37	26·6	19·39
	31	76·33	−0·47	−1·92	−0·19	1·93	95·7	15·76
June	1	88·52	−0·50	−3·12	−1·60	3·51	117·1	11·34
	2	100·71	−0·53	−4·17	−3·06	5·17	122·3	6·30
	3	112·91	−0·55	−5·01	−4·19	6·53	129·9	0·91
	4	125·10	−0·58	−5·64	−5·25	7·70	132·9	355·44
	5	137·29	−0·61	−6·05	−6·06	8·57	135·0	350·20
	6	149·49	−0·64	−6·20	−6·58	9·04	136·7	345·45
	7	161·69	−0·66	−6·10	−6·76	9·11	137·9	341·40
	8	173·90	−0·68	−5·73	−6·57	8·72	138·9	338·28
	9	186·11	−0·71	−5·10	−6·00	7·88	139·6	336·24
	10	198·34	−0·73	−4·22	−5·07	6·60	140·2	335·48
	11	210·57	−0·75	−3·11	−3·80	4·91	140·7	336·12
	12	222·81	−0·77	−1·79	−2·28	2·90	141·9	338·78
	13	235·05	−0·79	−0·33	−0·59	0·68	150·8	341·96
	14	247·30	−0·81	+1·19	+1·14	1·65	313·8	346·97
	15	259·56	−0·83	+2·68	+2·80	3·87	316·3	352·90
	16	271·82	−0·85	+4·04	+4·25	5·86	316·5	359·24
	17	284·07	−0·87	+5·14	+5·41	7·46	316·5	5·46
	18	296·32	−0·89	+5·93	+6·21	8·59	316·3	11·06
	19	308·57	−0·91	+6·33	+6·64	9·17	316·4	15·82
	20	320·81	−0·93	+6·32	+6·71	9·22	316·7	19·57
	21	333·04	−0·95	+5·92	+6·44	8·75	317·4	22·26
	22	345·27	−0·97	+5·17	+5·86	7·81	318·6	23·92
	23	357·50	−0·99	+4·14	+5·04	6·52	320·6	24·53
	24	9·72	−1·01	+2·90	+4·01	4·95	324·1	24·12
	25	21·93	−1·03	+1·54	+2·81	3·20	331·3	22·70
	26	34·14	−1·06	+0·14	+1·50	1·51	354·7	20·28
	27	46·35	−1·08	−1·21	+0·12	1·22	84·3	16·93
	28	58·55	−1·10	−2·44	−1·27	2·75	117·5	12·72
	29	70·75	−1·12	−3·48	−2·63	4·36	127·1	7·81
	30	82·95	−1·14	−4·29	−3·88	5·78	132·1	2·44
July	1	95·14	−1·16	−4·85	−4·97	6·95	135·7	356·90
	2	107·33	−1·18	−5·14	−5·83	7·77	138·6	351·49
	3	119·53	−1·20	−5·17	−6·39	8·22	141·0	346·52
	4	131·72	−1·22	−4·97	−6·63	8·29	143·1	342·24
	5	143·92	−1·24	−4·56	−6·49	7·93	144·9	338·87

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1901.	°	°	°	°	°	°	°
July 6	156·12	−1·25	−3·98	−5·99	7·19	146·4	336·58
7	168·33	−1·27	−3·27	−5·13	6·08	147·5	335·52
8	180·55	−1·28	−2·42	−3·95	4·63	148·5	335·82
9	192·78	−1·29	−1·49	−2·52	2·93	149·4	337·54
10	205·01	−1·30	−0·46	−0·93	1·04	153·7	340·72
11	217·25	−1·31	+0·63	+0·73	0·96	319·2	345·39
12	229·49	−1·32	+1·75	+2·34	2·92	323·2	350·74
13	241·74	−1·33	+2·85	+3·80	4·75	323·1	356·88
14	253·99	−1·34	+3·86	+5·01	6·32	322·4	3·11
15	266·25	−1·35	+4·70	+5·90	7·54	321·5	8·97
16	278·50	−1·36	+5·28	+6·43	8·32	320·6	14·09
17	290·75	−1·37	+5·55	+6·59	8·62	319·9	18·30
18	303·00	−1·38	+5·47	+6·40	8·42	319·5	21·43
19	315·24	−1·39	+5·02	+5·90	7·75	319·6	23·48
20	327·48	−1·40	+4·25	+5·12	6·65	320·3	24·45
21	339·71	−1·42	+3·20	+4·13	5·23	322·2	24·38
22	351·94	−1·43	+1·95	+2·97	3·55	326·7	23·27
23	4·16	−1·44	+0·58	+1·69	1·79	341·1	21·16
24	16·38	−1·45	−0·82	+0·35	0·89	66·9	18·10
25	28·59	−1·46	−2·13	−1·02	2·36	115·6	14·17
26	40·80	−1·47	−3·29	−2·36	4·05	125·6	9·48
27	53·00	−1·48	−4·21	−3·62	5·55	130·7	4·26
28	65·20	−1·49	−4·84	−4·72	6·76	134·3	358·72
29	77·39	−1·50	−5·12	−5·61	7·60	137·6	353·20
30	89·58	−1·50	−5·08	−6·23	8·04	140·8	347·98
31	101·76	−1·51	−4·71	−6·52	8·04	144·2	343·39
Aug. 1	113·95	−1·51	−4·09	−6·44	7·63	147·6	339·65
2	126·13	−1·52	−3·28	−5·97	6·81	151·2	337·00
3	138·32	−1·52	−2·35	−5·14	5·65	155·4	335·62
4	150·52	−1·52	−1·37	−3·99	4·22	161·1	335·60
5	162·72	−1·52	−0·40	−2·59	2·62	171·2	337·04
6	174·93	−1·52	+0·55	−1·04	1·18	207·9	339·89
7	187·15	−1·52	+1·44	+0·58	1·55	291·9	344·04
8	199·38	−1·52	+2·29	+2·16	3·15	313·3	349·25
9	211·61	−1·52	+3·08	+3·60	4·74	319·4	355·13
10	223·84	−1·51	+3·79	+4·81	6·12	321·8	1·25
11	236·08	−1·51	+4·40	+5·73	7·22	322·5	7·15
12	248·33	−1·51	+4·85	+6·31	7·95	322·5	12·48

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1901.	°	°	°	°	°	°	°
Aug. 13	260·58	−1·51	+5·09	+6·53	8·27	322·1	16·97
14	272·82	−1·51	+5·08	+6·41	8·18	321·6	20·47
15	285·07	−1·51	+4·79	+5·95	7·63	321·2	22·91
16	297·31	−1·50	+4·20	+5·22	6·70	321·2	24·27
17	309·55	−1·50	+3·32	+4·25	5·39	322·0	24·54
18	321·78	−1·50	+2·21	+3·10	3·81	324·5	23·75
19	334·01	−1·50	+0·91	+1·84	2·05	333·7	21·96
20	346·23	−1·50	−0·48	+0·50	0·69	43·8	19·20
21	358·45	−1·50	−1·89	−0·86	2·08	114·5	15·56
22	10·66	−1·50	−3·21	−2·19	3·89	124·3	11·13
23	22·87	−1·49	−4·35	−3·44	5·54	128·3	6·13
24	35·07	−1·49	−5·21	−4·56	6·92	131·2	0·73
25	47·26	−1·48	−5·74	−5·49	7·94	133·7	355·21
26	59·45	−1·48	−5·87	−6·15	8·51	136·3	349·87
27	71·63	−1·47	−5·58	−6·51	8·57	139·4	344·99
28	83·81	−1·46	−4·91	−6·50	8·15	142·9	340·87
29	95·98	−1·45	−3·91	−6·10	7·25	147·3	337·76
30	108·16	−1·44	−2·69	−5·31	5·95	153·1	335·87
31	120·33	−1·43	−1·35	−4·17	4·38	162·1	335·44
Sept. 1	132·51	−1·42	+0·01	−2·75	2·75	180·2	336·50
2	144·69	−1·40	+1·29	−1·16	1·74	228·0	339·07
3	156·88	−1·39	+2·43	+0·49	2·48	281·4	343·00
4	169·08	−1·38	+3·40	+2·10	4·00	301·7	348·04
5	181·28	−1·36	+4·19	+3·55	5·49	310·3	353·80
6	193·49	−1·35	+4·82	+4·78	6·79	314·8	359·85
7	205·71	−1·33	+5·25	+5·72	7·76	317·5	5·76
8	217·93	−1·32	+5·51	+6·34	8·40	319·0	11·17
9	230·16	−1·30	+5·58	+6·60	8·64	319·8	15·83
10	242·39	−1·29	+5·45	+6·51	8·49	320·1	19·58
11	254·62	−1·28	+5·09	+6·10	7·94	320·2	22·31
12	266·86	−1·27	+4·51	+5·39	7·03	320·1	23·99
13	279·09	−1·25	+3·68	+4·44	5·76	320·4	24·59
14	291·32	−1·24	+2·65	+3·31	4·24	321·3	24·13
15	303·55	−1·22	+1·43	+2·03	2·48	324·8	22·64
16	315·77	−1·21	+0·07	+0·68	0·68	354·1	20·15
17	327·99	−1·20	−1·36	−0·69	1·52	116·9	16·76
18	340·20	−1·18	−2·79	−2·04	3·46	126·2	12·60
19	352·41	−1·17	−4·12	−3·31	5·29	128·8	7·81

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1901.	°	°	°	°	°	°	°
Sept. 20	4·62	−1·15	−5·28	−4·45	6·90	130·1	2·61
21	16·81	−1·14	−6·16	−5·41	8·20	131·3	357·20
22	29·00	−1·12	−6·69	−6·14	9·07	132·5	351·86
23	41·18	−1·10	−6·80	−6·58	9·47	134·1	346·85
24	53·36	−1·08	−6·47	−6·67	9·29	135·9	342·43
25	65·53	−1·06	−5·68	−6·38	8·55	138·3	338·89
26	77·69	−1·04	−4·49	−5·69	7·25	141·7	336·47
27	89·85	−1·01	−2·99	−4·61	5·50	147·0	335·42
28	102·01	−0·99	−1·30	−3·21	3·46	158·0	335·90
29	114·16	−0·96	+0·43	−1·58	1·64	195·2	337·99
30	126·33	−0·94	+2·10	+0·16	2·12	274·3	341·61
Oct. 1	138·49	−0·91	+3·58	+1·86	4·04	297·5	346·52
2	150·67	−0·89	+4·82	+3·42	5·91	305·4	352·29
3	162·85	−0·86	+5·76	+4·74	7·46	309·5	358·44
4	175·03	−0·84	+6·40	+5·75	8·60	311·9	4·47
5	187·23	−0·82	+6·73	+6·41	9·29	313·6	10·03
6	199·43	−0·79	+6·80	+6·72	9·57	314·7	14·86
7	211·63	−0·77	+6·58	+6·68	9·38	315·4	18·80
8	223·84	−0·75	+6·13	+6·30	8·79	315·8	21·75
9	236·06	−0·72	+5·45	+5·64	7·84	316·0	23·68
10	248·27	−0·70	+4·57	+4·71	6·56	315·9	24·57
11	260·49	−0·68	+3·51	+3·59	5·02	315·6	24·39
12	272·70	−0·66	+2·30	+2·32	3·26	315·3	23·18
13	284·92	−0·64	+0·96	+0·95	1·35	314·7	20·96
14	297·13	−0·61	−0·45	−0·44	0·63	134·4	17·80
15	309·34	−0·59	−1·89	−1·82	2·62	133·9	13·84
16	321·55	−0·57	−3·30	−3·12	4·54	133·4	9·29
17	333·75	−0·55	−4·62	−4·30	6·31	133·0	4·15
18	345·94	−0·52	−5·77	−5·31	7·84	132·6	358·85
19	358·13	−0·50	−6·68	−6·09	9·05	132·4	353·58
20	10·32	−0·47	−7·26	−6·61	9·81	132·3	348·54
21	22·49	−0·45	−7·47	−6·80	10·10	132·3	344·00
22	34·67	−0·42	−7·24	−6·75	9·90	133·0	340·19
23	46·83	−0·39	−6·55	−6·11	8·96	133·0	337·33
24	58·98	−0·36	−5·43	−5·18	7·50	133·6	335·68
25	71·13	−0·33	−3·91	−3·88	5·51	134·8	335·45
26	83·28	−0·30	−2·10	−2·30	3·11	137·6	336·83
27	95·41	−0·27	−0·15	−0·54	0·56	164·5	339·85

Greenwich Midnight.		Selenographical Colong. of the Sun.	Selenographical Lat. of the Sun.	Geocentric Libration Sel. Long. of the Earth.	Geocentric Libration Lat. of the Earth.	Combined Amount.	Direction.	C.
1901.		°	°	°	°	°	°	°
Oct.	28	107·55	−0·24	+1·82	+1·27	2·22	304·9	344·39
	29	119·70	−0·20	+3·65	+2·97	4·70	309·1	350·07
	30	131·85	−0·17	+5·23	+4·44	6·86	310·3	356·35
	31	144·00	−0·14	+6·46	+5·59	8·55	310·7	2·69
Nov.	1	156·16	−0·11	+7·29	+6·37	9·67	311·1	8·60
	2	168·33	−0·08	+7·71	+6·77	10·27	311·3	13·76
	3	180·50	−0·05	+7·74	+6·79	10·30	311·3	17·98
	4	192·69	−0·03	+7·41	+6·48	9·85	311·2	21·19
	5	204·88	0·00	+6·76	+5·85	8·94	310·9	23·33
	6	217·07	+0·02	+5·86	+4·97	7·68	310·3	24·49
	7	229·26	+0·05	+4·76	+3·88	6·14	309·2	24·56
	8	241·46	+0·08	+3·51	+2·64	4·40	307·0	23·59
	9	253·66	+0·10	+2·15	+1·28	2·50	300·8	21·63
	10	265·86	+0·13	+0·74	−0·12	0·75	260·8	18·70
	11	278·06	+0·15	−0·69	−1·52	1·67	155·6	14·93
	12	290·26	+0·17	−2·09	−2·85	3·54	143·7	10·44
	13	302·46	+0·20	−3·42	−4·06	5·31	139·9	5·45
	14	314·65	+0·23	−4·63	−5·11	6·90	137·8	0·20
	15	326·84	+0·25	−5·70	−5·94	8·23	136·2	354·92
	16	339·03	+0·28	−6·55	−6·52	9·25	134·9	349·87
	17	351·20	+0·30	−7·14	−6·79	9·86	133·6	345·24
	18	3·38	+0·33	−7·42	−6·74	10·03	132·3	341·30
	19	15·54	+0·36	−7·34	−6·33	9·70	130·8	338·20
	20	27·70	+0·39	−6·87	−5·56	8·84	129·0	336·14
	21	39·85	+0·42	−5·99	−4·44	7·45	126·5	335·33
	22	51·99	+0·45	−4·71	−3·01	5·59	122·6	335·98
	23	64·13	+0·48	−3·08	−1·34	3·36	113·5	338·21
	24	76·26	+0·51	−1·20	+0·45	1·28	69·4	342·04
	25	88·39	+0·54	+0·81	+2·22	2·36	340·0	347·28
	26	100·52	+0·57	+2·80	+3·82	4·73	323·8	353·49
	27	112·65	+0·60	+4·61	+5·14	6·91	318·1	0·06
	28	124·78	+0·63	+6·10	+6·09	8·62	315·0	6·41
	29	136·93	+0·66	+7·17	+6·63	9·77	312·8	12·07
	30	149·07	+0·68	+7·78	+6·77	10·31	311·0	16·78
Dec.	1	161·23	+0·71	+7·91	+6·53	10·25	309·5	20·27
	2	173·38	+0·73	+7·61	+5·97	9·67	308·1	22·91
	3	185·55	+0·76	+6·92	+5·14	8·62	306·6	24·32
	4	197·72	+0·78	+5·93	+4·09	7·20	304·6	24·66

Greenwich Midnight.	Selenographical Colong. of the Sun.	Selenographical Lat. of the Sun.	Geocentric Libration Sel. Long. of the Earth.	Geocentric Libration Lat. of the Earth.	Combined Amount.	Direction.	C.
1901.	°	°	°	°	°	°	°
Dec. 5	209·90	+0·80	+4·71	+2·88	5·52	301·4	23·96
6	222·08	+0·82	+3·35	+1·56	3·70	295·0	22·23
7	234·26	+0·84	+1·92	+0·18	1·93	275·4	19·55
8	246·45	+0·86	+0·49	−1·20	1·30	202·2	15·97
9	258·64	+0·88	−0·90	−2·54	2·69	160·5	11·63
10	270·83	+0·90	−2·20	−3·77	4·37	149·7	6·73
11	283·02	+0·92	−3·37	−4·84	5·89	145·2	1·47
12	295·21	+0·94	−4·39	−5·71	7·21	142·4	356·13
13	307·39	+0·96	−5·24	−6·33	8·21	140·4	350·98
14	319·57	+0·98	−5·90	−6·65	8·89	138·4	346·24
15	331·75	+1·00	−6·36	−6·66	9·21	136·3	342·13
16	343·93	+1·02	−6·58	−6·33	9·13	133·9	338·87
17	356·09	+1·05	−6·54	−5·66	8·65	130·9	336·57
18	8·26	+1·07	−6·22	−4·67	7·78	126·9	335·41
19	20·41	+1·09	−5·59	−3·38	6·53	121·2	335·56
20	32·55	+1·11	−4·63	−1·86	4·99	111·9	337·15
21	44·69	+1·14	−3·36	−0·19	3·36	93·2	340·25
22	56·82	+1·16	−1·81	+1·52	2·36	50·0	344·79
23	68·95	+1·18	−0·06	+3·15	3·15	1·1	350·51
24	81·07	+1·20	+1·76	+4·56	4·89	338·9	356·98
25	93·19	+1·22	+3·53	+5·65	6·66	328·0	3·54
26	105·31	+1·24	+5·06	+6·35	8·12	321·5	9·67
27	117·44	+1·26	+6·24	+6·62	9·10	316·7	14·96
28	129·57	+1·28	+6·98	+6·49	9·53	312·9	19·17
29	141·71	+1·29	+7·23	+6·01	9·39	309·7	22·18
30	153·86	+1·30	+7·02	+5·23	8·75	306·7	23·99
31	166·01	+1·32	+6·39	+4·21	7·65	303·4	24·69
1902. Jan. 1	178·16	+1·33	+5·41	+3·03	6·20	299·2	24·28

The longitudes are reckoned in the plane of the Moon's equator, the axis of reference being the radius which passes through the mean centre of the visible disc. This axis therefore rotates with the Moon, and is not fixed in space.

The inclination of the Moon's equator to the ecliptic is taken as 1°·523, the value used in the *Connaissance des Temps*, that given by the *Nautical Almanac* being 1°·536.

The physical librations in longitude and latitude, as given by Professor Franz's formulæ, have been applied; their values are taken from the *Berliner Jahrbuch* for the days given there, and interpolated by a graphical method for the other days. But the

signs in the *Jahrbuch* require to be reversed in order to reduce to the system used here.

The colongitude of the Sun is 90° (or 450°) *minus* his selenographical longitude. It also is the selenographical longitude of the morning terminator reckoned eastward from the mean centre of the disc. Hence its value is approximately 270°, 0°, 90°, 180° at new Moon, first quarter, full Moon, last quarter respectively. The longitude of the evening terminator is of course 180° greater or less than that of the morning one.

When the geocentric libration in longitude is positive, the region brought into view is on the west limb; when negative, on the east.

When the geocentric libration in latitude is positive, the region brought into view is at the Moon's north pole; when negative, at the south.

The column "Combined Amount" gives the distance between the apparent and mean centres of the disc, and the column "Direction" gives the position-angle of the apparent centre from the mean centre, or, which is the same thing, the position-angle of the region which is most carried into view by libration. The angles are reckoned eastward from the northern extremity of the Moon's axis.

C denotes the geocentric position-angle of the northern extremity of the Moon's axis measured eastward from the northernmost point of the disc. This quantity is given now for the first time, at the suggestion of Professor W. H. Pickering. It has been computed by the second formula given in the Preface to the *Nautical Almanac*, but the coordinates of the Moon's equator have been taken from the *Connaissance des Temps*, so as to make this column consistent with the rest of the ephemeris.

The terms "East" and "West" are used throughout with reference to our sky, and not as they would appear to an observer on the Moon.

At the suggestion of Mr. S. A. Saunder I give the method for finding the altitude of the Sun at a given point on the Moon whose position is defined: (1) by selenographical longitude and latitude; (2) by direction cosines.

In either case the Sun's selenographical colongitude and latitude (K, L supposed) must be found by interpolation from the ephemeris for the given time.

In the first case let the given point be in the position longitude M, latitude N. Longitudes are reckoned from the meridian passing through the mean centre of the disc, and the positive direction is that towards Mare Crisium. North latitudes are considered positive.

Then

$$\text{sine Sun's altitude} = \sin L \sin N + \cos L \cos N \sin (K + M).$$

In the second case let ξ, η, ζ be the direction cosines of the given point. The axes are (1) that diameter of the Moon's

equator which is 90° from the mean centre of the disc; (2) the Moon's polar axis; (3) the diameter through the mean centre of the disc. The positive directions are as above. Mr. Saunder, I understand, proposes to issue some maps of portions of the Moon's surface from which the coordinates ξ, η, ζ can be taken at sight.

Then the Sun's direction cosines are:

$$\cos K \cos L, \sin L, \sin K \cos L,$$

and sine Sun's altitude

$$= \xi \cos K \cos L + \eta \sin L + \zeta \sin K \cos L.$$

Neither formula is convenient when the Sun's altitude is very great, for an angle near 90° cannot be accurately determined from its sine. However, when the Sun is high the shadows are so inconspicuous that it is not necessary to compute his altitude with great accuracy.

Examples:

(1) To find the Sun's altitude at Mösting A, 1901 April $27^{d}\ 9^{h}$, G.M.T.

By interpolation from the ephemeris $K = 19^{\circ}{\cdot}68$, $L = +0^{\circ}{\cdot}45$.

Place of Mösting A, $M = -5^{\circ}\ 10'{\cdot}3$, $N = -3^{\circ}\ 11'{\cdot}4$.
(From *Monthly Notices*, lx. 3, p. 181).

∴ sine Sun's altitude

$$= -\sin 0^{\circ}{\cdot}45 \sin 3^{\circ}\ 11'{\cdot}4 + \cos 0^{\circ}{\cdot}45 \cos 3^{\circ}\ 11'{\cdot}4 \sin(19^{\circ}{\cdot}68 - 5^{\circ}{\cdot}17)$$

$$= -{\cdot}0007 + {\cdot}2502 = +{\cdot}2495.$$

∴ Sun's altitude $= 14^{\circ}{\cdot}45$.

(2) To find the Sun's altitude at Euclides 1901 October $25^{d}\ 13^{h}$, G.M.T. By interpolation from the ephemeris $K = 71^{\circ}{\cdot}64$, $L = -0^{\circ}{\cdot}33$.

Place of Euclides $\xi = -{\cdot}4887$, $\eta = -{\cdot}1281$.
(From *Monthly Notices*, lx. 3, p. 182.)

$$\text{And } \zeta = \sqrt{1 - \xi^2 - \eta^2} = \sqrt{1 - {\cdot}2388 - {\cdot}0164} = \sqrt{{\cdot}7448} = +{\cdot}8630.$$

$$\begin{aligned}\text{Then sine Sun's altitude} &= -{\cdot}4887 \cos 71^{\circ}{\cdot}64 \cos 0^{\circ}{\cdot}33 \\ &\quad + {\cdot}1281 \sin 0^{\circ}{\cdot}33 \\ &\quad + {\cdot}8630 \sin 71^{\circ}{\cdot}64 \cos 0{\cdot}33 \\ &= -{\cdot}1539 \quad + {\cdot}0001 \quad + {\cdot}8190 \quad = +{\cdot}6652\end{aligned}$$

Hence, Sun's altitude $= 41^{\circ}{\cdot}70$.

Benvenue, 55 *Ulundi Road, Blackheath, S.E.*
1900 *October* 27.

Greenwich Midnight.	Selenographical Colong. of the Sun.	Selenographical Lat. of the Sun.	Geocentric Libration Sel. Long. of the Earth.	Geocentric Libration Lat. of the Earth.	Combined Amount.	Direction.	C.
1901.	°	°	°	°	°	°	°
Mar. 14	204·45	+1·34	−7·73	−4·73	9·06	121·5	356·61
15	216·64	+1·32	−7·73	−5·66	9·58	126·2	351·13
16	228·85	+1·31	−7·25	−6·30	9·61	131·0	346·05
17	241·05	+1·29	−6·24	−6·59	9·07	136·6	341·67
18	253·26	+1·28	−4·79	−6·46	8·05	143·4	338·30
19	265·48	+1·27	−3·01	−5·90	6·62	153·0	336·19
20	277·70	+1·25	−1·05	−4·92	5·03	168·0	335·57
21	289·92	+1·24	+0·92	−3·58	3·70	194·4	336·57
22	302·13	+1·23	+2·74	−2·01	3·40	233·7	339·19
23	314·34	+1·21	+4·28	−0·33	4·29	265·6	343·25
24	326·55	+1·20	+5·47	+1·35	5·63	283·9	348·40
25	338·75	+1·19	+6·29	+2·89	6·92	294·7	354·20
26	350·94	+1·17	+6·72	+4·23	7·94	302·2	0·17
27	3·12	+1·16	+6·82	+5·30	8·64	307·9	5·89
28	15·30	+1·14	+6·61	+6·08	8·98	312·6	11·07
29	27·47	+1·12	+6·16	+6·54	8·99	316·7	15·52
30	39·65	+1·10	+5·47	+6·68	8·63	320·7	19·14
31	51·81	+1·08	+4·61	+6·51	7·98	324·7	21·85
April 1	63·98	+1·06	+3·58	+6·05	7·03	329·4	23·61
2	76·15	+1·04	+2·43	+5·32	5·85	335·5	24·41
3	88·31	+1·01	+1·16	+4·37	4·52	345·1	24·20
4	100·48	+0·99	−0·18	+3·23	3·24	3·2	23·00
5	112·65	+0·97	−1·59	+1·95	2·52	39·2	20·78
6	124·82	+0·94	−2·98	+0·59	3·04	78·8	17·62
7	136·99	+0·92	−4·33	−0·80	4·40	100·5	13·61
8	149·16	+0·89	−5·58	−2·17	5·99	111·3	8·92
9	161·35	+0·87	−6·64	−3·47	7·49	117·6	3·79
10	173·53	+0·84	−7·45	−4·63	8·78	121·9	358·29
11	185·72	+0·82	−7·91	−5·60	9·69	125·3	352·89
12	197·92	+0·79	−7·98	−6·30	10·17	128·3	347·79
13	210·13	+0·77	−7·60	−6·69	10·13	131·4	343·25
14	222·34	+0·75	−6·74	−6·69	9·50	134·8	339·54
15	234·56	+0·72	−5·44	−6·28	8·31	139·1	336·91
16	246·79	+0·70	−3·76	−5·44	6·61	145·4	335·62
17	259·02	+0·68	−1·82	−4·21	4·59	156·6	335·88
18	271·25	+0·66	+0·22	−2·67	2·68	184·7	337·80
19	283·49	+0·64	+2·19	−0·95	2·39	246·5	341·34
20	295·72	+0·62	+3·96	+0·83	4·05	281·8	346·23

Greenwich Midnight.	Selenographical Colong. of the Sun.	Lat. of the Sun.	Geocentric Libration Sel. Long. of the Earth.	Lat. of the Earth.	Combined Amount.	Direction.	C.
1901.	°	°	°	°	°	°	°
April 21	307·95	+0·60	+5·40	+2·51	5·95	294·9	352·03
22	320·17	+0·57	+6·45	+3·99	7·58	301·7	358·20
23	332·39	+0·55	+7·09	+5·19	8·78	306·2	4·22
24	344·60	+0·53	+7·31	+6·07	9·50	309·7	9·73
25	356·80	+0·50	+7·15	+6·61	9·75	312·8	14·48
26	9·01	+0·48	+6·65	+6·80	9·52	315·6	18·36
27	21·20	+0·45	+5·88	+6·68	8·91	318·6	21·32
28	33·39	+0·42	+4·88	+6·26	7·93	322·1	23·31
29	45·58	+0·40	+3·71	+5·57	6·70	326·3	24·34
30	57·76	+0·37	+2·42	+4·64	5·23	332·5	24·38
May 1	69·94	+0·34	+1·06	+3·52	3·68	343·2	23·40
2	82·12	+0·31	−0·33	+2·25	2·27	8·3	21·45
3	94·30	+0·28	−1·71	+0·88	1·92	62·8	18·51
4	106·49	+0·25	−3·04	−0·54	3·09	100·1	14·68
5	118·67	+0·22	−4·27	−1·94	4·69	114·4	10·11
6	130·85	+0·19	−5·36	−3·27	6·28	121·4	5·00
7	143·04	+0·16	−6·27	−4·46	7·69	125·4	359·62
8	155·23	+0·13	−6·94	−5·47	8·83	128·2	354·23
9	167·43	+0·10	−7·32	−6·23	9·61	130·4	349·09
10	179·64	+0·07	−7·37	−6·69	9·95	132·2	344·47
11	191·85	+0·04	−7·06	−6·80	9·80	133·9	340·59
12	204·06	+0·02	−6·37	−6·52	9·11	135·7	337·68
13	216·29	−0·01	−5·30	−5·84	7·88	137·8	335·92
14	228·52	−0·03	−3·90	−4·77	6·16	140·7	335·55
15	240·75	−0·06	−2·22	−3·37	4·04	146·6	336·73
16	253·00	−0·08	−0·40	−1·71	1·76	166·8	339·53
17	265·25	−0·10	+1·46	+0·07	1·46	272·7	343·86
18	277·50	−0·12	+3·20	+1·83	3·69	299·8	349·40
19	289·74	−0·15	+4·73	+3·45	5·85	306·1	355·49
20	301·98	−0·17	+5·91	+4·80	7·62	309·1	1·91
21	314·22	−0·19	+6·70	+5·83	8·88	311·0	7·82
22	326·45	−0·22	+7·06	+6·50	9·59	312·6	13·00
23	338·68	−0·24	+7·00	+6·80	9·76	314·2	17·28
24	350·90	−0·27	+6·56	+6·76	9·41	315·9	20·59
25	3·12	−0·30	+5·79	+6·40	8·63	317·9	22·89
26	15·33	−0·33	+4·75	+5·77	7·48	320·5	24·19
27	27·54	−0·35	+3·51	+4·89	6·02	324·3	24·49
28	39·74	−0·38	+2·17	+3·81	4·39	330·3	23·79

Greenwich Midnight.	Selenographical Colong. of the Sun.	Lat. of the Sun.	Geocentric Libration Sel. Long. of the Earth.	Lat. of the Earth.	Combined Amount.	Direction.	C.
1901.	°	°	°	°	°	°	°
May 29	51·94	−0·41	+0·78	+2·57	2·69	343·1	22·08
30	64·13	−0·44	−0·61	+1·22	1·37	26·6	19·39
31	76·33	−0·47	−1·92	−0·19	1·93	95·7	15·76
June 1	88·52	−0·50	−3·12	−1·60	3·51	117·1	11·34
2	100·71	−0·53	−4·17	−3·06	5·17	122·3	6·30
3	112·91	−0·55	−5·01	−4·19	6·53	129·9	0·91
4	125·10	−0·58	−5·64	−5·25	7·70	132·9	355·44
5	137·29	−0·61	−6·05	−6·06	8·57	135·0	350·20
6	149·49	−0·64	−6·20	−6·58	9·04	136·7	345·45
7	161·69	−0·66	−6·10	−6·76	9·11	137·9	341·40
8	173·90	−0·68	−5·73	−6·57	8·72	138·9	338·28
9	186·11	−0·71	−5·10	−6·00	7·88	139·6	336·24
10	198·34	−0·73	−4·22	−5·07	6·60	140·2	335·48
11	210·57	−0·75	−3·11	−3·80	4·91	140·7	336·12
12	222·81	−0·77	−1·79	−2·28	2·90	141·9	338·78
13	235·05	−0·79	−0·33	−0·59	0·68	150·8	341·96
14	247·30	−0·81	+1·19	+1·14	1·65	313·8	346·97
15	259·56	−0·83	+2·68	+2·80	3·87	316·3	352·90
16	271·82	−0·85	+4·04	+4·25	5·86	316·5	359·24
17	284·07	−0·87	+5·14	+5·41	7·46	316·5	5·46
18	296·32	−0·89	+5·93	+6·21	8·59	316·3	11·06
19	308·57	−0·91	+6·33	+6·64	9·17	316·4	15·82
20	320·81	−0·93	+6·32	+6·71	9·22	316·7	19·57
21	333·04	−0·95	+5·92	+6·44	8·75	317·4	22·26
22	345·27	−0·97	+5·17	+5·86	7·81	318·6	23·92
23	357·50	−0·99	+4·14	+5·04	6·52	320·6	24·53
24	9·72	−1·01	+2·90	+4·01	4·95	324·1	24·12
25	21·93	−1·03	+1·54	+2·81	3·20	331·3	22·70
26	34·14	−1·06	+0·14	+1·50	1·51	354·7	20·28
27	46·35	−1·08	−1·21	+0·12	1·22	84·3	16·93
28	58·55	−1·10	−2·44	−1·27	2·75	117·5	12·72
29	70·75	−1·12	−3·48	−2·63	4·36	127·1	7·81
30	82·95	−1·14	−4·29	−3·88	5·78	132·1	2·44
July 1	95·14	−1·16	−4·85	−4·97	6·95	135·7	356·90
2	107·33	−1·18	−5·14	−5·83	7·77	138·6	351·49
3	119·53	−1·20	−5·17	−6·39	8·22	141·0	346·52
4	131·72	−1·22	−4·97	−6·63	8·29	143·1	342·24
5	143·92	−1·24	−4·56	−6·49	7·93	144·9	338·87

Greenwich Midnight.		Selenographical Colong. of the Sun.	Selenographical Lat. of the Sun.	Geocentric Libration Sel. Long. of the Earth.	Geocentric Libration Lat. of the Earth.	Combined Amount.	Direction.	C.
1901.		°	°	°	°	°	°	°
July	6	156·12	−1·25	−3·98	−5·99	7·19	146·4	336·58
	7	168·33	−1·27	−3·27	−5·13	6·08	147·5	335·52
	8	180·55	−1·28	−2·42	−3·95	4·63	148·5	335·82
	9	192·78	−1·29	−1·49	−2·52	2·93	149·4	337·54
	10	205·01	−1·30	−0·46	−0·93	1·04	153·7	340·72
	11	217·25	−1·31	+0·63	+0·73	0·96	319·2	345·39
	12	229·49	−1·32	+1·75	+2·34	2·92	323·2	350·74
	13	241·74	−1·33	+2·85	+3·80	4·75	323·1	356·88
	14	253·99	−1·34	+3·86	+5·01	6·32	322·4	3·11
	15	266·25	−1·35	+4·70	+5·90	7·54	321·5	8·97
	16	278·50	−1·36	+5·28	+6·43	8·32	320·6	14·09
	17	290·75	−1·37	+5·55	+6·59	8·62	319·9	18·30
	18	303·00	−1·38	+5·47	+6·40	8·42	319·5	21·43
	19	315·24	−1·39	+5·02	+5·90	7·75	319·6	23·48
	20	327·48	−1·40	+4·25	+5·12	6·65	320·3	24·45
	21	339·71	−1·42	+3·20	+4·13	5·23	322·2	24·38
	22	351·94	−1·43	+1·95	+2·97	3·55	326·7	23·27
	23	4·16	−1·44	+0·58	+1·69	1·79	341·1	21·16
	24	16·38	−1·45	−0·82	+0·35	0·89	66·9	18·10
	25	28·59	−1·46	−2·13	−1·02	2·36	115·6	14·17
	26	40·80	−1·47	−3·29	−2·36	4·05	125·6	9·48
	27	53·00	−1·48	−4·21	−3·62	5·55	130·7	4·26
	28	65·20	−1·49	−4·84	−4·72	6·76	134·3	358·72
	29	77·39	−1·50	−5·12	−5·61	7·60	137·6	353·20
	30	89·58	−1·50	−5·08	−6·23	8·04	140·8	347·98
	31	101·76	−1·51	−4·71	−6·52	8·04	144·2	343·39
Aug.	1	113·95	−1·51	−4·09	−6·44	7·63	147·6	339·65
	2	126·13	−1·52	−3·28	−5·97	6·81	151·2	337·00
	3	138·32	−1·52	−2·35	−5·14	5·65	155·4	335·62
	4	150·52	−1·52	−1·37	−3·99	4·22	161·1	335·60
	5	162·72	−1·52	−0·40	−2·59	2·62	171·2	337·04
	6	174·93	−1·52	+0·55	−1·04	1·18	207·9	339·89
	7	187·15	−1·52	+1·44	+0·58	1·55	291·9	344·04
	8	199·38	−1·52	+2·29	+2·16	3·15	313·3	349·25
	9	211·61	−1·52	+3·08	+3·60	4·74	319·4	355·13
	10	223·84	−1·51	+3·79	+4·81	6·12	321·8	1·25
	11	236·08	−1·51	+4·40	+5·73	7·22	322·5	7·15
	12	248·33	−1·51	+4·85	+6·31	7·95	322·5	12·48

Greenwich Midnight.	Selenographical Colong. of the Sun.	Lat.	Geocentric Libration Sel. Long. of the Earth.	Lat.	Combined Amount.	Direction.	C.
1901.	°	°	°	°	°	°	°
Aug. 13	260·58	−1·51	+5·09	+6·53	8·27	322·1	16·97
14	272·82	−1·51	+5·08	+6·41	8·18	321·6	20·47
15	285·07	−1·51	+4·79	+5·95	7·63	321·2	22·91
16	297·31	−1·50	+4·20	+5·22	6·70	321·2	24·27
17	309·55	−1·50	+3·32	+4·25	5·39	322·0	24·54
18	321·78	−1·50	+2·21	+3·10	3·81	324·5	23·75
19	334·01	−1·50	+0·91	+1·84	2·05	333·7	21·96
20	346·23	−1·50	−0·48	+0·50	0·69	43·8	19·20
21	358·45	−1·50	−1·89	−0·86	2·08	114·5	15·56
22	10·66	−1·50	−3·21	−2·19	3·89	124·3	11·13
23	22·87	−1·49	−4·35	−3·44	5·54	128·3	6·13
24	35·07	−1·49	−5·21	−4·56	6·92	131·2	0·73
25	47·26	−1·48	−5·74	−5·49	7·94	133·7	355·21
26	59·45	−1·48	−5·87	−6·15	8·51	136·3	349·87
27	71·63	−1·47	−5·58	−6·51	8·57	139·4	344·99
28	83·81	−1·46	−4·91	−6·50	8·15	142·9	340·87
29	95·98	−1·45	−3·91	−6·10	7·25	147·3	337·76
30	108·16	−1·44	−2·69	−5·31	5·95	153·1	335·87
31	120·33	−1·43	−1·35	−4·17	4·38	162·1	335·44
Sept. 1	132·51	−1·42	+0·01	−2·75	2·75	180·2	336·50
2	144·69	−1·40	+1·29	−1·16	1·74	228·0	339·07
3	156·88	−1·39	+2·43	+0·49	2·48	281·4	343·00
4	169·08	−1·38	+3·40	+2·10	4·00	301·7	348·04
5	181·28	−1·36	+4·19	+3·55	5·49	310·3	353·80
6	193·49	−1·35	+4·82	+4·78	6·79	314·8	359·85
7	205·71	−1·33	+5·25	+5·72	7·76	317·5	5·76
8	217·93	−1·32	+5·51	+6·34	8·40	319·0	11·17
9	230·16	−1·30	+5·58	+6·60	8·64	319·8	15·83
10	242·39	−1·29	+5·45	+6·51	8·49	320·1	19·58
11	254·62	−1·28	+5·09	+6·10	7·94	320·2	22·31
12	266·86	−1·27	+4·51	+5·39	7·03	320·1	23·99
13	279·09	−1·25	+3·68	+4·44	5·76	320·4	24·59
14	291·32	−1·24	+2·65	+3·31	4·24	321·3	24·13
15	303·55	−1·22	+1·43	+2·03	2·48	324·8	22·64
16	315·77	−1·21	+0·07	+0·68	0·68	354·1	20·15
17	327·99	−1·20	−1·36	−0·69	1·52	116·9	16·76
18	340·20	−1·18	−2·79	−2·04	3·46	126·2	12·60
19	352·41	−1·17	−4·12	−3·31	5·29	128·8	7·81

Greenwich Midnight.	Selenographical Colong. of the Sun.	Lat. of the Sun.	Geocentric Libration Sel. Long. of the Earth.	Lat. of the Earth.	Combined Amount.	Direction.	C.
1901.	°	°	°	°	°	°	°
Sept. 20	4·62	−1·15	−5·28	−4·45	6·90	130·1	2·61
21	16·81	−1·14	−6·16	−5·41	8·20	131·3	357·20
22	29·00	−1·12	−6·69	−6·14	9·07	132·5	351·86
23	41·18	−1·10	−6·80	−6·58	9·47	134·1	346·85
24	53·36	−1·08	−6·47	−6·67	9·29	135·9	342·43
25	65·53	−1·06	−5·68	−6·38	8·55	138·3	338·89
26	77·69	−1·04	−4·49	−5·69	7·25	141·7	336·47
27	89·85	−1·01	−2·99	−4·61	5·50	147·0	335·42
28	102·01	−0·99	−1·30	−3·21	3·46	158·0	335·90
29	114·16	−0·96	+0·43	−1·58	1·64	195·2	337·99
30	126·33	−0·94	+2·10	+0·16	2·12	274·3	341·61
Oct. 1	138·49	−0·91	+3·58	+1·86	4·04	297·5	346·52
2	150·67	−0·89	+4·82	+3·42	5·91	305·4	352·29
3	162·85	−0·86	+5·76	+4·74	7·46	309·5	358·44
4	175·03	−0·84	+6·40	+5·75	8·60	311·9	4·47
5	187·23	−0·82	+6·73	+6·41	9·29	313·6	10·03
6	199·43	−0·79	+6·80	+6·72	9·57	314·7	14·86
7	211·63	−0·77	+6·58	+6·68	9·38	315·4	18·80
8	223·84	−0·75	+6·13	+6·30	8·79	315·8	21·75
9	236·06	−0·72	+5·45	+5·64	7·84	316·0	23·68
10	248·27	−0·70	+4·57	+4·71	6·56	315·9	24·57
11	260·49	−0·68	+3·51	+3·59	5·02	315·6	24·39
12	272·70	−0·66	+2·30	+2·32	3·26	315·3	23·18
13	284·92	−0·64	+0·96	+0·95	1·35	314·7	20·96
14	297·13	−0·61	−0·45	−0·44	0·63	134·4	17·80
15	309·34	−0·59	−1·89	−1·82	2·62	133·9	13·84
16	321·55	−0·57	−3·30	−3·12	4·54	133·4	9·29
17	333·75	−0·55	−4·62	−4·30	6·31	133·0	4·15
18	345·94	−0·52	−5·77	−5·31	7·84	132·6	358·85
19	358·13	−0·50	−6·68	−6·09	9·05	132·4	353·58
20	10·32	−0·47	−7·26	−6·61	9·81	132·3	348·54
21	22·49	−0·45	−7·47	−6·80	10·10	132·3	344·00
22	34·67	−0·42	−7·24	−6·75	9·90	133·0	340·19
23	46·83	−0·39	−6·55	−6·11	8·96	133·0	337·33
24	58·98	−0·36	−5·43	−5·18	7·50	133·6	335·68
25	71·13	−0·33	−3·91	−3·88	5·51	134·8	335·45
26	83·28	−0·30	−2·10	−2·30	3·11	137·6	336·83
27	95·41	−0·27	−0·15	−0·54	0·56	164·5	339·85

the groups are given in the following table, together with the corresponding quantities calculated for a provisional orbit, found by trial to approximately satisfy the observations so far obtained:—

Day from beginning of Year.	Observed Angle.	Computed Angle.	C−O.	Observed Mean Daily Motion.	Computed Mean Daily Motion.	Computed Radius Vector.
d	°	°	°	°	°	
87·7	290·7	292·7	+2·0			
				2·45	3·08	0·97
92·8	278·2	277·0	−1·2			
				2·41	2·82	1·01
105·9	246·6	240·0	−6·6			
				3·69	3·16	1·03
121·2	190·1	191·7	+1·6			
				3·55	3·71	0·91
134·8	141·8	141·3	−0·5			
				3·89	3·47	0·90
147·2	93·6	98·3	+4·7			
				3·32	3·25	0·95
156·5	62·7	68·1	+5·4			
				3·47	3·71	0·94
169·6	17·3	19·6	+2·3			
				4·47	4·18	0·85
175·8	349·6	353·7	+4·1			
				3·70	3·84	0·84

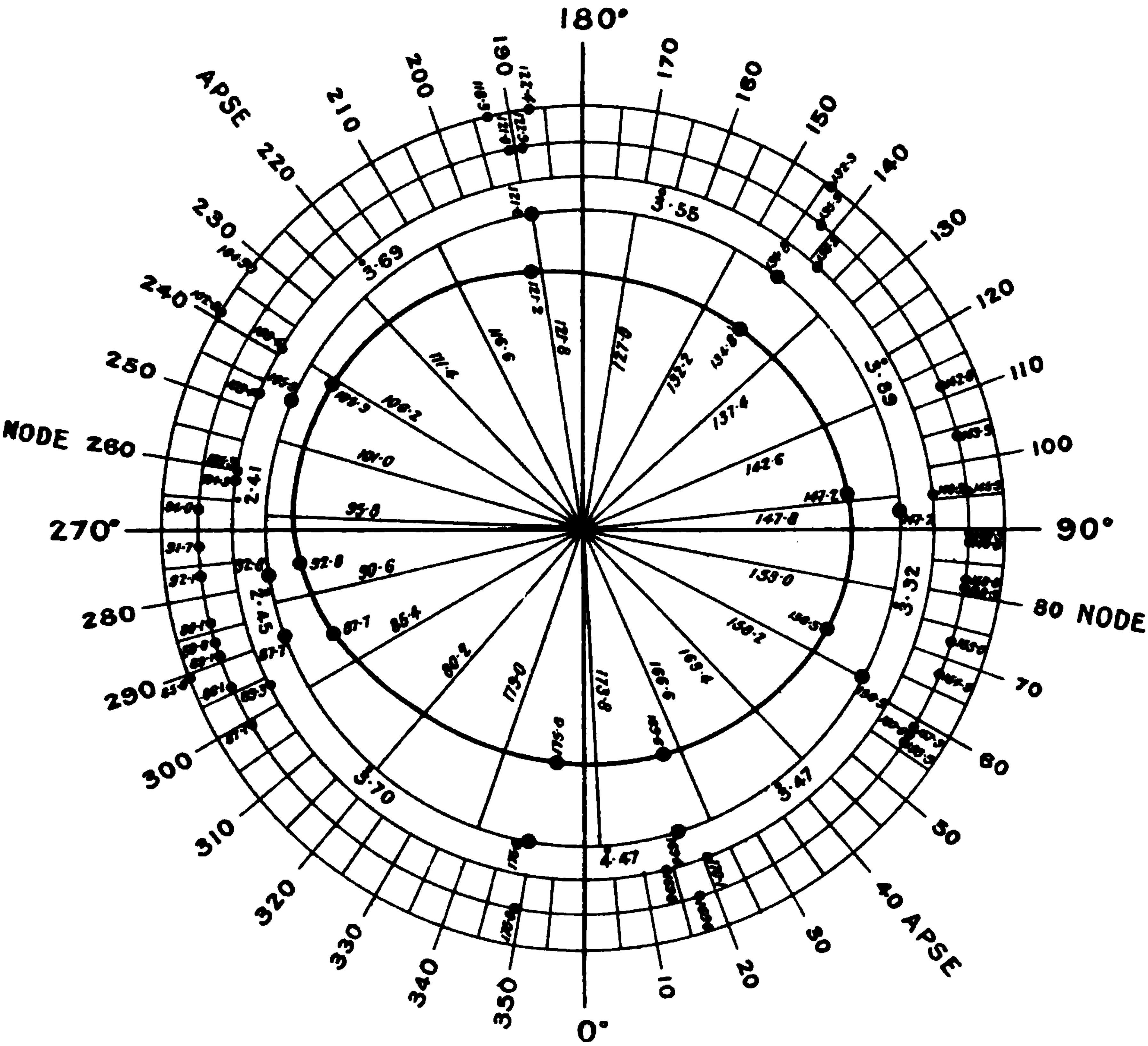
The values of the mean daily motion show that the apparent path is not far from circular, and a closer examination indicates that the plane of the orbit is inclined about 30° to 35°, the line of nodes being at about 80°, and that there is a very small eccentricity in the true orbit. This accords satisfactorily with Mr. Newall's spectroscopic observations, which, with a period of 104 days, give 1900 June 4, represented by 154^d in the table, as the epoch of maximum relative velocity, corresponding to position-angle 76° in the apparent orbit, which is quite close to the line of nodes at about 80° as indicated by the visual observations. For the provisional orbit used for the calculated position-angles and mean daily motions the following elements have been taken:—

Inclination, 30°. Position-angle of node, 80°.
Eccentricity, 0·05. Position-angle of periastron, 40°.

The values of C—O indicate that this orbit represents the observations so far available within the limits of error for such a difficult double star, but further observations and an alteration in the assumed period of revolution would doubtless materially modify these elements, especially the eccentricity and periastron. The comparison with this provisional orbit, however, suffices to indicate that the visual observations accord satisfactorily with the spectroscopic observations as regards the period of revolution, the date of passing through the node (corresponding approximately to date of maximum velocity of the solar component) and small eccentricity.

The diagram exhibits the results of the two tables graphically, the position-angles observed during the three revolutions being indicated on the three circles with the corresponding dates,

Position Angles of Capella observed as a Double Star at the Royal Observatory, Greenwich, 1900, with the deduced Apparent Ellipse.



The observations of position angle are indicated on three circles by the day of the year, 104 days and 208 days respectively being subtracted in the second and third revolutions to make them comparable with the first.
The means of groups are indicated on the innermost circle, and the corresponding computed positions on the apparent ellipse.

expressed in days reckoned from 1900 January $1^{h}\cdot0$ G.M.T. (astronomical), 104 days being subtracted for the second revolution, and 208 days for the third. On the innermost circle the mean observed position-angles for groups are indicated with the dates, and within this the apparent ellipse (provisional) with the position-angles corresponding to the mean dates of groups. The position-angles for every 18° of mean anomaly (representing 5·2 days) are also shown for convenience. The observed mean daily motion for the intervals between groups is also shown round the innermost circle.

As regards the distance of the components, three actual measures have been made, besides estimates by different observers, which on the whole accord fairly with the measures, due allowance being made for the variation in distance at different parts of the apparent orbit. The following are the measures of distance made, together with the radii computed for the apparent orbit in terms of the mean distance :—

1900	d	"		
Sept. 6	248	0·09	0·94*a*	6 measures by Mr. Bryant, micrometer read by Mr. Lewis.
20	158	0·06	0·93*a*	2 measures by Mr. Bryant.
22	160	0·06	0·92*a*	Measures by Mr. Lewis, in terms of the breadth of the spider lines.*

From these measures it would result that $a=0''\cdot08$, and therefore that the maximum distance of the components would be $0''\cdot083$, at about 100^{d}, and the minimum $0''\cdot066$, at about 170^{d}. This value for a accords as closely as can be expected with Mr. Newall's data from spectroscopic observations in combination with Dr. Elkin's value of the parallax, viz., $0''\cdot08$. In fact, with an inclination of 30°, $a=\frac{52}{93}\times\frac{1}{\sin 30^{\circ}}\times0''\cdot08=0''\cdot09$.

It is of interest in this connection to note that *κ Pegasi* has been observed at Greenwich (by Mr. Lewis and also by Mr. Dyson in 1896 and 1897), when the distance of the components (as inferred from the angular velocities) was only $0''\cdot05$ or $0''\cdot06$, and that observations of 42 *Comæ* (Σ 1728) were obtained (also by Mr. Dyson and Mr. Lewis) just before and just after nearest approach or occultation, when the distance was in each case between $0''\cdot05$ and $0''\cdot04$, the distances being fixed with great accuracy from the circumstances of the orbit. It may be noted also that *κ Pegasi* (which is now again becoming a difficult object) was observed on the last four nights on which *Capella* was observed, viz. November

* There are two spider lines in the filar micrometer, and Mr. Lewis found that the thinner line, $0''\cdot08$ in breadth, covered the star disk completely in all positions except that corresponding to the direction of elongation 60°, while the thicker wire, $0''\cdot14$ in breadth covered it in that position. It results that the apparent star disk under the conditions of observation was less than $0''\cdot08$ in diameter for each component, and that the distance of the components was about $0''\cdot06$.

23, 27, December 7 and 10, and that the elongation in the case of *Capella* was noted as being quite as distinct as in the case of *κ Pegasi*, for which Mr. Lewis estimated the distance as under 0″·1. On December 10 Mr. Lewis (though unable to get a satisfactory measure of position-angle owing to unsteadiness of the image shortly before the sky clouded over) satisfied himself of a distinct elongation in *Capella*, the definition being very fine momentarily, so that he was able to *count* eight rings round the star, using a magnifying power of 1120, there being at least ten or more complete rings visible.

The two components of *Capella* do not differ much in brightness, but there is a consensus of opinion amongst the observers that the position-angles as given indicate the direction of the fainter star. Mr. Bryant in particular has noted his impression as to this on several occasions, and I can confirm this on July 13, when the star appeared distinctly egg-shaped, with the smaller end in the position-angle given. On September 19 I had the impression that the fainter star was in the first quadrant, not the third, but the elongation was then smaller, and I do not feel so much confidence as to which end of the elongated image was the smaller.

In making the observations, neutral-tinted or deep-blue shades were used to reduce the brightness of the star. Many of the observations were made in the daytime, when the brightness was naturally much reduced.

Royal Observatory, Greenwich:
1900 *December* 14.

ζ Herculis. By T. Lewis.

R.A.	$16^h\ 37^m\ 31^s$	1900.	Mag. A.	3·0	Yellow.
N.P.D.	$58°\ 13'\ 1''$		Mag. B.	6·5	Bluish Green.

Sir William Herschel found this star to be double on 1782 July 18, and on July 21 he measured the position-angle as 69°·3. In 1795 he noted that it was in the n.f. quadrant, and remarked that the distance was smaller than in 1782. In 1802 and 1803 he failed to separate the pair, but measured the angle on three occasions:—

1802·74	219°·2
1802·81	5°·7
1803·29	116°·8

Thus, while it was evident that the pair formed a binary system of short period, these observations left the matter in a very unsatisfactory state, which did not improve by the failure of Sir J.

Herschel and South to see the companion from 1821 to 1825. With regard to the failure in 1802 and 1803, Dr. See states that "at this time the position-angle was 174°·5 and distance 1″·24," and it therefore seems strange that Herschel could not make any satisfactory measures.

Since Herschel's time three revolutions of the companion have been completed, and yet there are certain circumstances connected with the system which require elucidation. For instance, Dr. See computed an orbit in 1895, and so recently as 1900 Dr. Doolittle, using observations down to 1897·6, made a careful investigation, and deduced what may be considered as the most satisfactory orbit. Yet, when the ephemerides are compared we see that they both fail, *e.g.* :—

	See.		Doolittle.		Observed.	
	°	″	°	″	°	″
1899·5	289·7	0·47	273·9	0·59	263	0·60
1900·5	258·4	·58	247·7	·77	240	0·78
1901·5	233·0	·80	230·6	·92		

It must, however, be understood that as periastron passage occurred in 1898, the ephemeris is here subject to large errors, due in great measure to the inequality of the components and their closeness. Still, the errors are too large.

The present paper is an attempt to set forth the peculiarities of motion in this system, and by an appeal to the Greenwich Transit Circle observations get some idea of the causes. For convenience the subject is dealt with in three distinct parts.

(1) Discussion of micrometric measures.

(2) Discussion of meridian observations and their combination with the micrometric measures.

(3) Discussion of circumstances arising from these, and remarks on magnitude, colour, and proper motion.

Part I.

Discussion of Micrometer Measures.

All the micrometric measures of this pair which could be found have been tabulated in the order of date and yearly means formed according to the following plan :—

The result of	1 night's	measures	received	a	weight	1
,,	2 or 3 nights'	,,	,,	,,	,,	2
,,	4, 5 or 6	,,	,,	,,	,,	3
,,	over 6	,,	,,	,,	,,	4

The yearly means thus obtained differ but little from those obtained by adopting any other similar system of weighting. These means were then plotted and a line drawn through them in

such a manner as to make individual residuals as small as possible, no regard being paid to the number of inflexions. From these smoothed means the position-angles and distances at the commencement of each year were read off and tabulated. These positions were then laid down as in fig. 1, where N represents the true north point and A the principal component, which is assumed

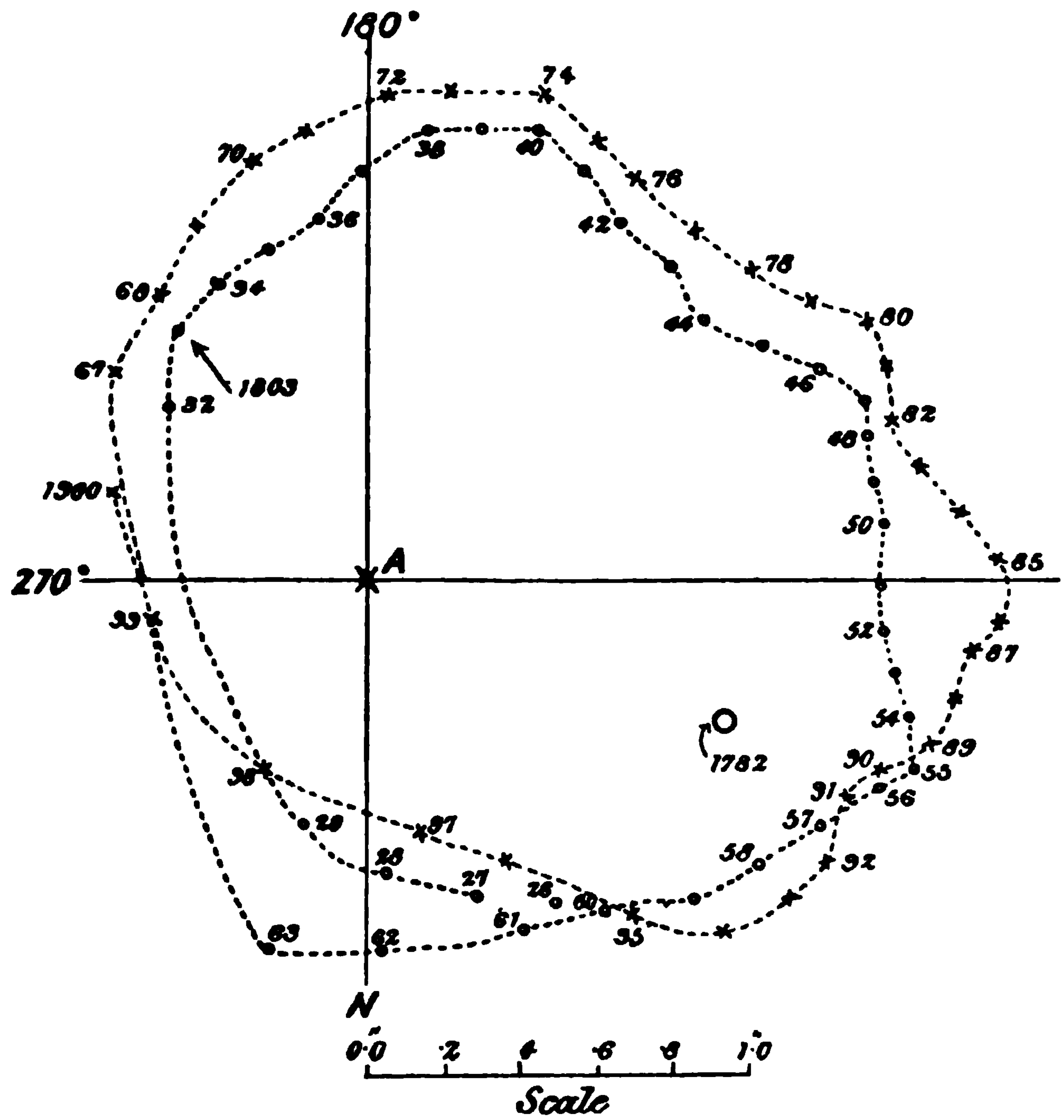


FIG. 1.—Positions from yearly means of angles and distances, A being the principal component and assumed fixed.

at rest. It is at once apparent that no single ellipse could satisfy these positions, for

(1) The series of positions 1832 to 1860 are inside those for the period 1867 to 1895.

(2) A radius vector from A passes through

1832	and	1867,	giving a period of		35	years
1837	„	$1871\frac{1}{2}$	„	„	$34\frac{1}{2}$	„
1844	„	1878	„	„	34	„
1851	„	$1885\frac{1}{2}$	„	„	$34\frac{1}{2}$	„
1859	„	1893	„	„	35	„

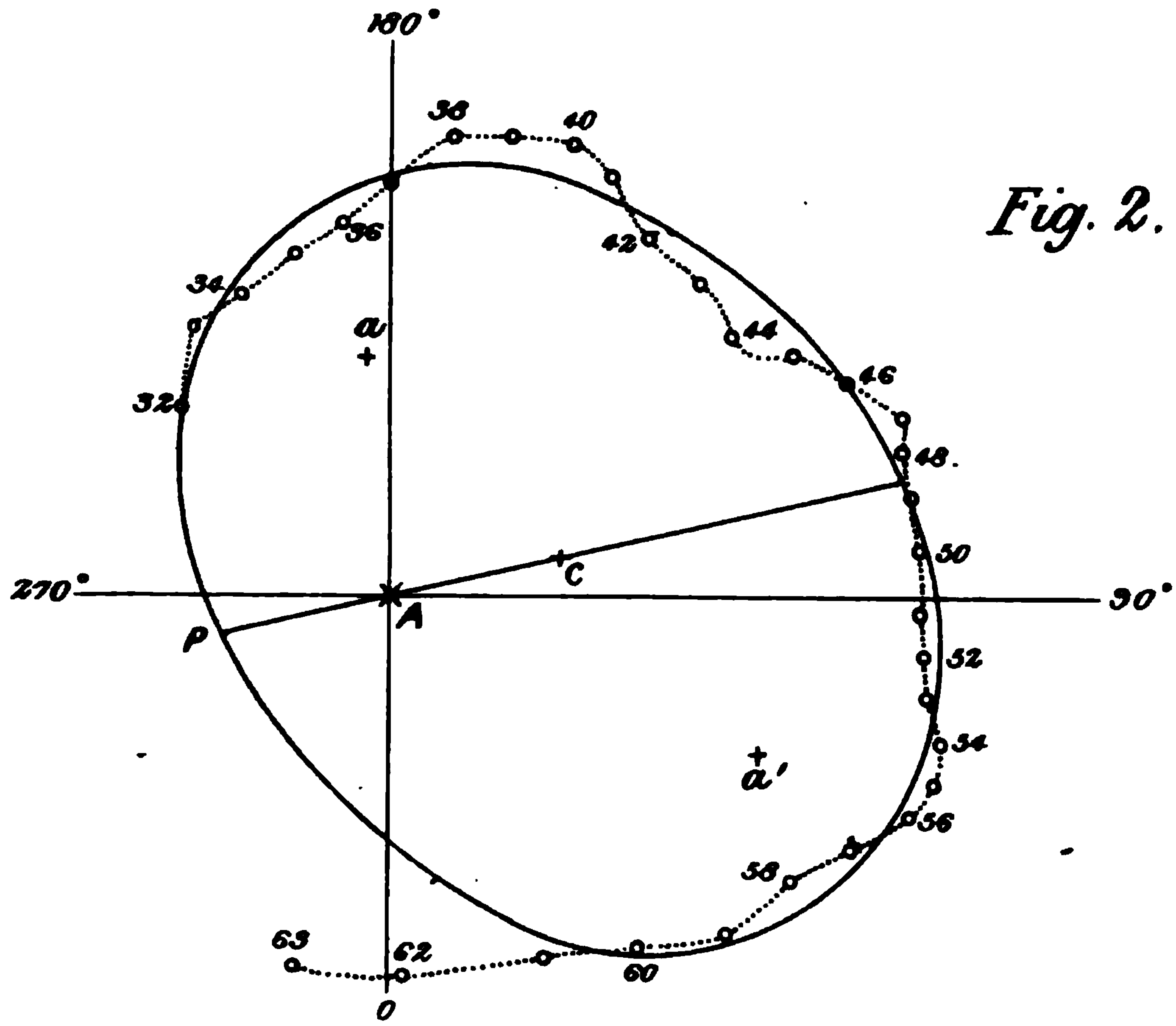

180°
270°
90°
0
A
C
P
a
a'
32
34
36
38
40
42
44
46
48.
50
52
54
56
58
60
62
63

Fig. 2.

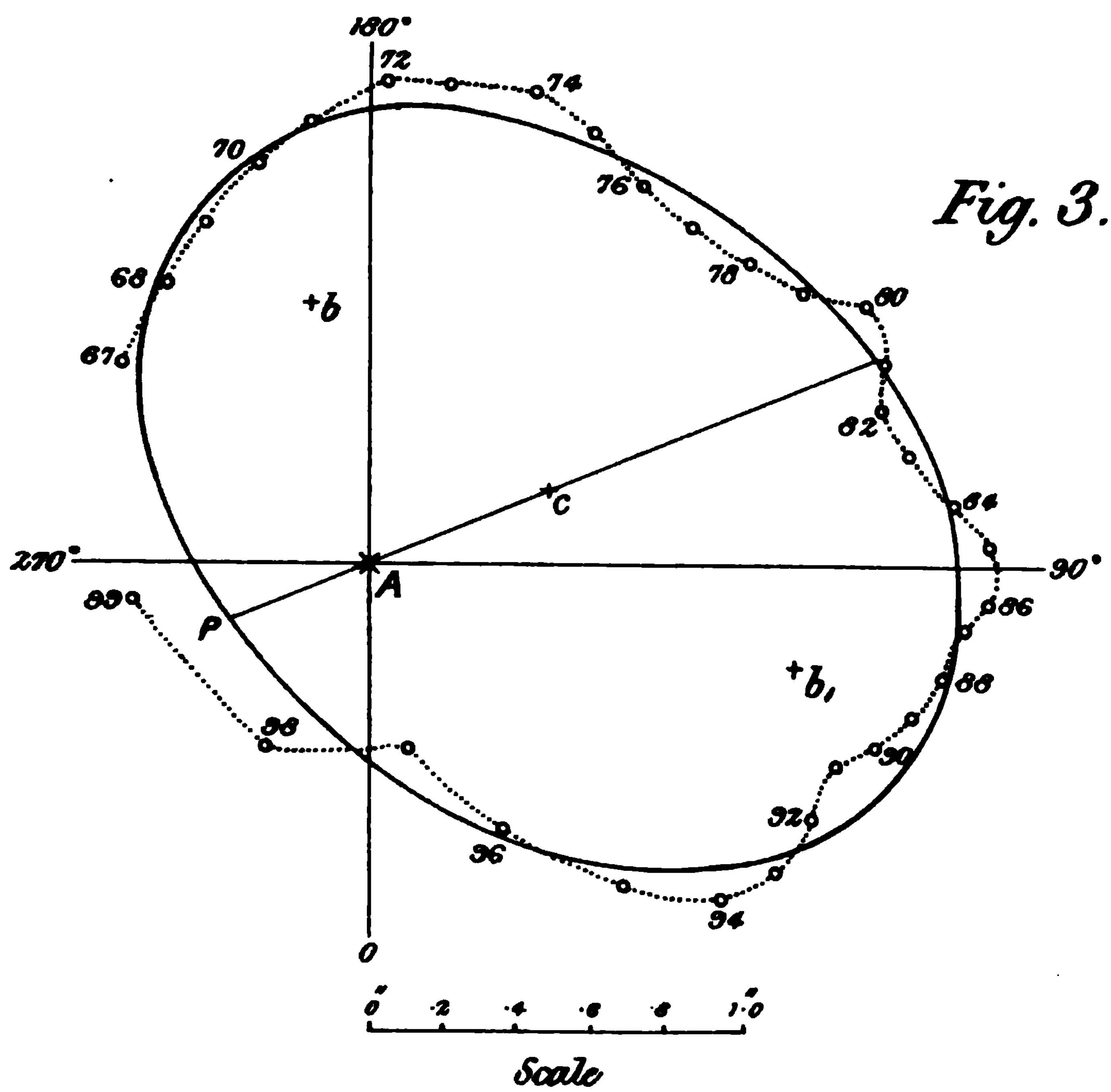

180°
270°
90°
0
A
C
P
b
b_1
67
68
70
72
74
76
78
80
82
84
86
88
90
92
94
96
98
99
0" ·2 ·4 ·6 ·8 1·0"
Scale

Fig. 3.

Consequently, each period has been treated separately and quite independently. Thus, in fig. 2 (Plate 2) the positions from 1832 to 1863 are laid down and an ellipse drawn which appears to best satisfy the measures. Similarly, fig. 3 (Plate 2) shows the positions from 1867 to 1899 with the ellipse best representing them.

These ellipses represent the apparent orbits, the elements of which are

	Fig. 2.	Fig. 3.
Length of major axis	$2''.19$	$2''.40$
Length of minor axis	1·67	1·75
Angle of major axis	$224^\circ.6$	$232^\circ.5$
Angle of periastron	283·6	293·8
Distance of star A from centre	$0''.45$	$0''.52$

and the corresponding elements of the true orbits :

τ	Periastron	1864·03	1898·09
P	Period in years	32·4	33·9.
a	Semi-major axis	$1''.25$	$1''.40$
e	Eccentricity	·504	·560
☊	Node	$35^\circ\ 29'$	$40^\circ\ 59'$
γ	Inclination	46 42	50 18
λ	Angle in true ellipse between node and periastron	254 36	258 48

It will be noticed that in fig. 1 observations are laid down for the years 1782, 1803, 1826 and 1829. I have made no use of these, the meagre material leaving too much room for individual prejudice. It so happens, however, that Maedler computed two orbits—one in 1842 and another in 1847—in which these measures necessarily have great weight, at least, this is so in the 1842 orbit. We may hence adopt Maedler's orbit for the period anterior to the two now given, provided we bear in mind the slender material from which it is deduced.

The three periods then give, in chronological order :

	τ	P	a	e	Ω	γ	λ
(1)	1829·50	31·46	$1''.19$	·455	39°	51°	262°
(2)	1864·03	32·4	1·25	·504	35	47	255
(3)	1898·09	33·9	1·40	·560	41	50	259

in which the chief points noticeable are

1. The increase in P, a, e.

2. The discrepancy between the period obtained from considerations of motion in each ellipse by itself and that deduced from one periastron passage to another.

3. The apparent constancy of the line of nodes and of the inclination.

The discrepancy in (2) is still more remarkable when we take into account the motion of Periastron, from which a decrease in the time from one periastron passage to the next might be expected. The discussion of the varying period led, amongst other things, to the interesting curve in fig. 4 (Plate 3). This curve results from the following process:—Using the smooth curve already obtained from the observed position-angles, the angles at the commencement of each year beginning at 1832 were tabulated, and the time noted when such angle recurred. Thus the angle for 1832·0 is 229°·0, and it occurs again in 1867·1, or 35·1 years later. A whole series of such time-intervals being obtained and laid down with the initial years as abscissæ.

To make this portion complete the computed orbits are appended.

P	T	e	a	Ω	γ	λ	Authority.	Date
			"	°	°	°		
31·47	1829·50	0·455	1·19	39·4	50·9	262·1	Maedler	1842
30·22	1830·42	·432	1·21	19·4	44·1	276·7	„	1847
36·36	1830·48	·448	...	214·4	43·7	284·9	Villarceau	...
37·21	1830·56	·438	...	37·2	39·4	266·9	Fletcher	1853
36·71	1830·24	·483	1·35	41·9	49·1	290·6	Villarceau	1854
34·22	1830·01	·424	1·22	45·9	34·9	209·5	Dunér	1871
36·61	1829·64	·551	1·37	27·0	50·2	266·7	Plummer	1871
34·58	1864·90	·405	1·36	26·1	51·1	261·c	Flammarion	1874
34·4	1864·8	·463	1·28	41·7	43·2	252·8	Doberck	1880
34·41	1864·78	·467	1·35	44·1	44·5	251·8	„	1881
35·0	1864·80	·497	1·43	37·5	51·8	258·3	See	1895
34·53	1863·89	·457	1·36	54·1	47·8	247·4	Doberck	1899
34·55	1864·46	·456	1·38	48·7	45·0	249·6	Doolittle	1900

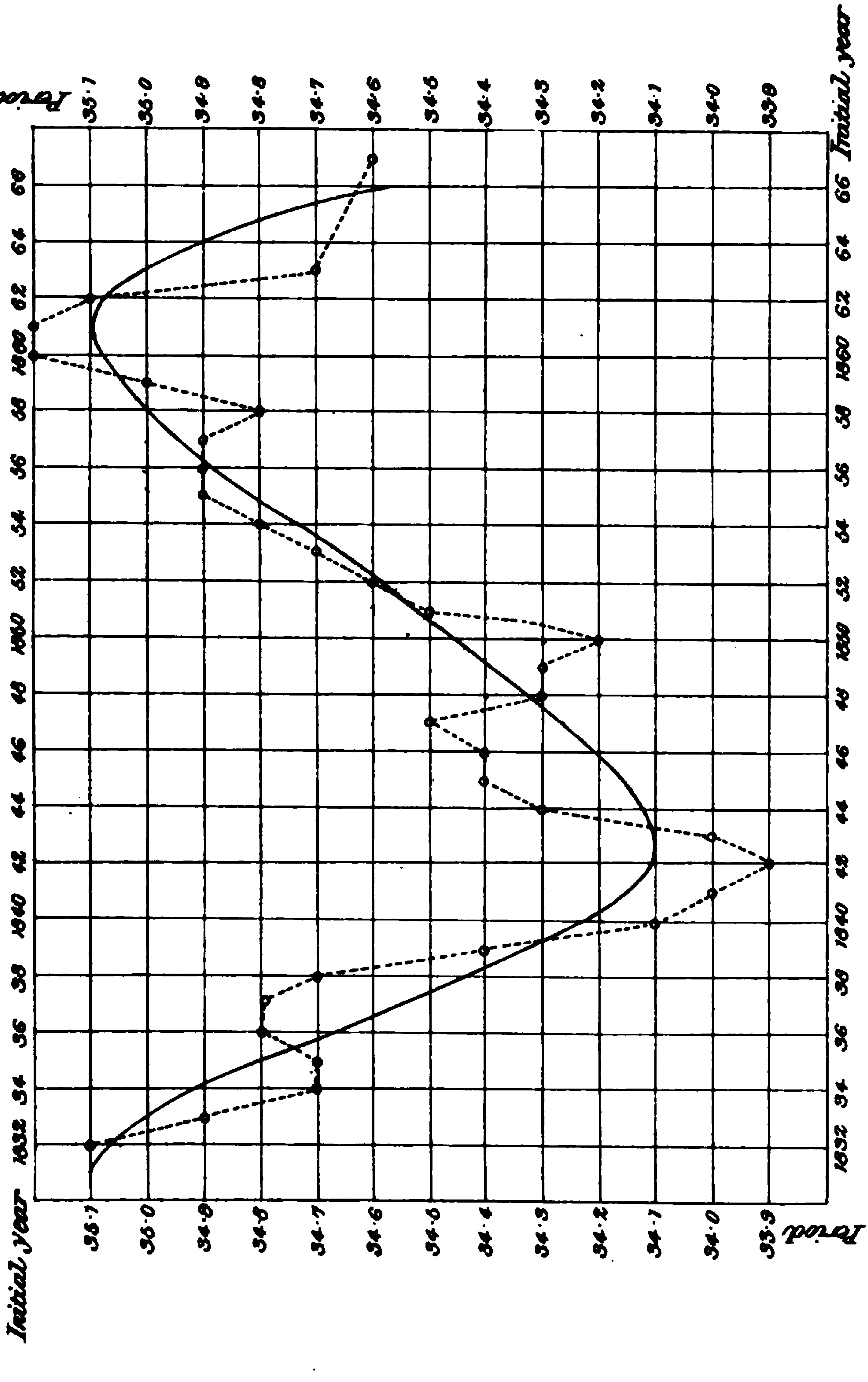
Micrometric Measures. Yearly Means.

The following Table is a summary of the yearly means of micrometer measures, weights being given according to the number of nights, as follows:

1	night=weight		1
2, 3	nights	„	2
4, 5, 6	„	„	3
over 6	„	„	4

also giving a weight of 1 to Smyth.

Fig. 4. Curve showing variation of Period



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OF
CALIFORNIA

Date.	Angle.	Dist.	w	Date.	Angle.	Dist.	w
	°	″			°	″	
1782·55	69·3	< 1·0	1	1866·70	232·1	0·81	12
1802·74	219	...	1	67·57	224·2	0·93	9
26·63	23·4	0·91	3	68·56	207·2	1·02	12
28·73	352·6	0·65	1	69·64	200·0	1·08	9
32·75	220·5	0·81	1	70·54	192·0	1·16	8
34·45	203·5	0·90	2	71·52	182·5	1·19	12
35·51	195·2	0·94	4	72·54	174·3	1·24	10
36·64	183·7	1·00	4	73·55	164·7	1·35	11
37·47	175·5	1·10	3	74·58	155·4	1·27	9
38·62	168·6	1·19	5	75·57	148·5	1·30	12
39·73	161·3	1·20	5	76·53	140·3	1·28	16
40·65	156·0	1·28	6	77·57	132·7	1·28	10
41·57	147·0	1·21	7	78·54	126·5	1·36	14
42·60	141·0	1·08	11	79·56	119·3	1·48	8
43·65	130·1	1·06	6	80·52	113·9	1·34	11
44·50	122·7	1·12	4	81·53	109·5	1·49	16
45·52	119·3	1·26	4	82·54	103·0	1·48	15
46·76	110·2	1·36	4	83·60	99·3	1·49	15
47·51	107·6	1·36	12	84·59	93·0	1·67	14
48·55	102·2	1·33	7	85·58	90·0	1·69	9
49·65	97·5	1·56	3	86·60	86·6	1·48	9
50·54	91·4	1·36	6	87·60	81·4	1·56	7
51·61	86·9	1·36	15	88·58	75·7	1·68	8
52·64	82·6	1·38	10	89·56	72·9	1·50	13
53·45	78·2	1·42	18	90·54	68·8	1·37	9
54·47	74·4	1·48	11	91·56	62·5	1·38	14
55·62	69·6	1·48	9	92·60	56·0	1·41	8
56·48	63·7	1·38	12	93·74	47·6	1·34	5
57·59	57·8	1·32	17	94·70	40·7	1·14	20
58·56	49·0	1·17	12	95·38	37·1	1·01	3
59·65	39·6	1·15	15	96·53	10·2	0·59	3
60·69	30·0	0·97	4	97·51	1·2	0·66	6
61·57	11·2	0·95	4	98·58	297·0	0·54	6
62·64	350·3	1·02	4	99·30	267·2	0·57	6
1863·49	343·1	...	3	1900·60	239·0	0·79	3

Position at Commencement of each Year as read from the Curves.

Date.	Angle.	Dist.	Date.	Angle.	Dist.
	°	″		°	″
1826·0	30·0	1·00	1860	36·5	1·07
27	20·0	0·88	61	24·0	1·00
28	5·0	0·78	62	1·0	0·98
29	348·0	0·72	63	346·0	1·00
30	...	...	64	...	...
31	...	...	65	...	...
32	229·0	0·73	66	...	...
33	217·5	0·83	67	230·0	0·87
34	207·5	0·88	68	215·5	0·96
35	197·5	0·93	69	204·0	1·04
36	188·5	0·97	70	195·0	1·11
37	180·5	1·04	71	187·0	1·18
38	173·0	1·15	72	178·5	1·25
39	166·0	1·21	73	170·5	1·29
40	159·5	1·22	74	160·5	1·32
41	153·0	1·20	75	152·5	1·29
42	145·5	1·14	76	145·0	1·27
43	137·5	1·09	77	137·0	1·27
44	128·0	1·11	78	130·0	1·31
45	121·0	1·18	79	123·5	1·40
46	115·0	1·30	80	117·5	1·49
47	109·5	1·37	81	112·0	1·50
48	105·0	1·34	82	107·0	1·49
49	100·0	1·35	83	101·5	1·48
50	95·5	1·37	84	96·5	1·57
51	90·0	1·36	85	92·0	1·65
52	85·5	1·37	86	88·0	1·64
53	80·5	1·43	87	83·5	1·58
54	76·0	1·45	88	79·0	1·57
55	71·5	1·48	89	75·0	1·53
56	67·0	1·45	90	71·0	1·44
57	62·0	1·36	91	66·5	1·38
58	54·0	1·27	92	60·0	1·39
59	45·5	1·18	93	53·0	1·39
60	36·5	1·07	94	46·0	1·29
61	24·0	1·00	95	38·5	1·09
62	1·0	0·98	96	27·5	0·86
1863	346·0	1·00	97	11·0	0·65
			98	328·0	0·56
			99	280·0	0·56
			1900	252·0	0·65

Fig. 5.

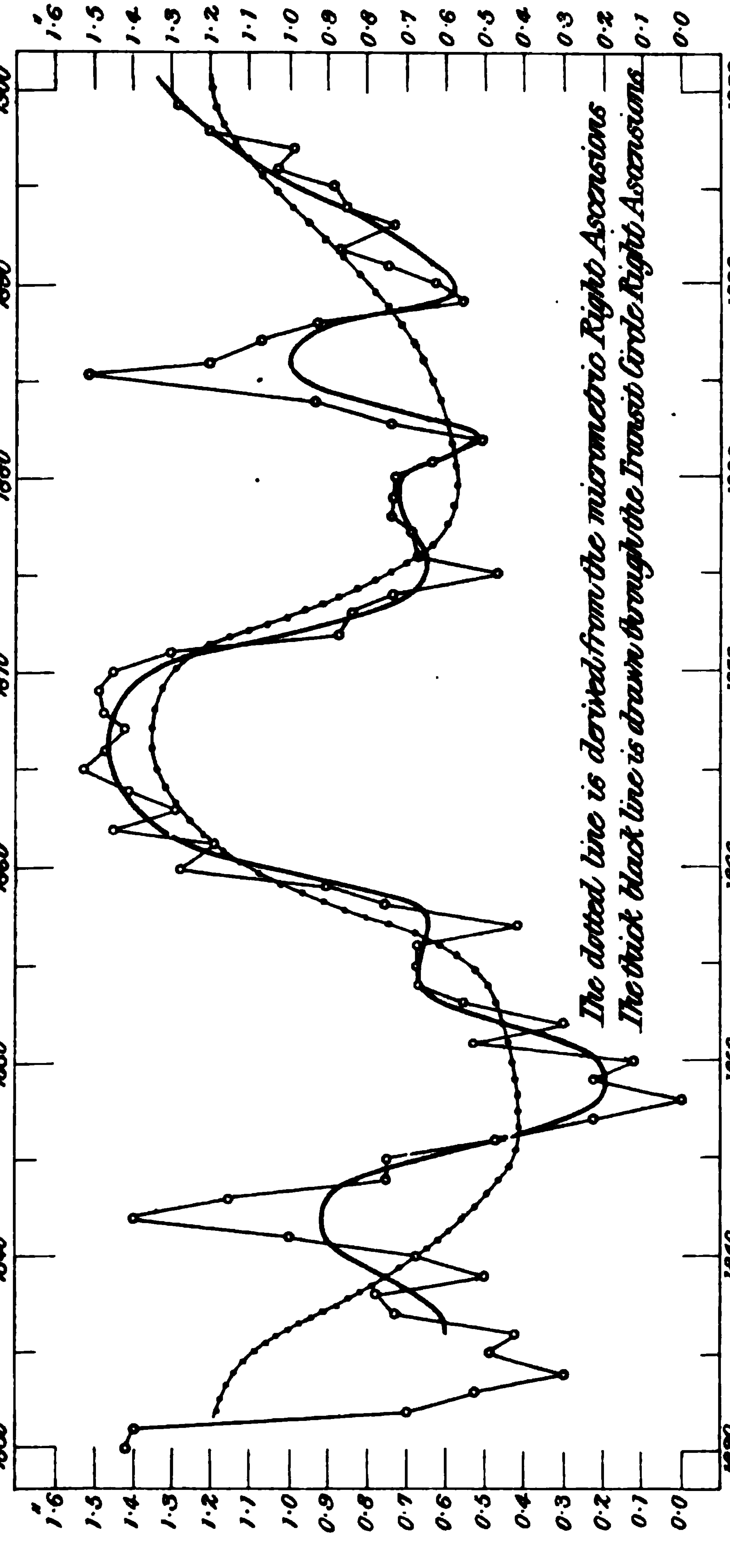
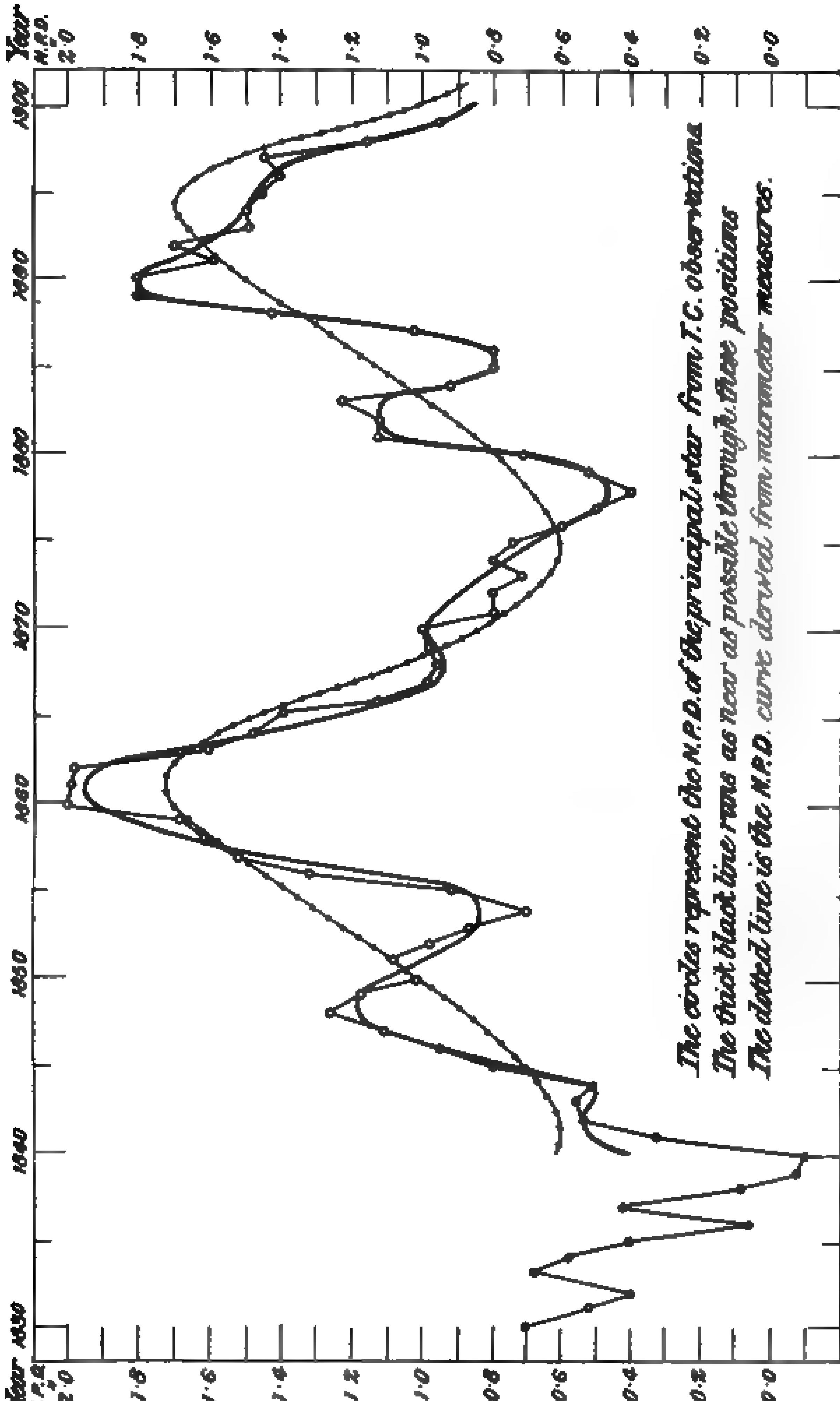

The dotted line is derived from the micrometric Right Ascensions
The thick black line is drawn through the Transit Circle Right Ascensions
1830
1840
1850
1860
1870
1880
1890
1900
0·0
0·1
0·2
0·3
0·4
0·5
0·6
0·7
0·8
0·9
1·0
1·1
1·2
1·3
1·4
1·5
1·6

Fig. 6.


Year
N.P.D.
2·0
1·8
1·6
1·4
1·2
1·0
0·8
0·6
0·4
0·2
0·0
1830
1840
1850
1860
1870
1880
1890
1900
The circles represent the N.P.D. of the principal star from T.C. observations
The thick black line runs as near as possible through these positions
The dotted line is the N.P.D. curve derived from micrometer measures.

PART II.

Discussion of Meridian Observations, and their Combination with the Micrometer Measures.

Having found the micrometric measures so interesting, the observations of the principal star, made on the meridian at Greenwich, were then collected. These were found so meagre before 1850 that in the initial stage they were not used. Starting, then, at 1850 the Greenwich Right Ascensions and North Polar Distances were tabulated and reduced to 1900. It was at once seen that every possible observation previous to 1850 was desirable. Consequently observations were collected from all sources (before 1850) and reduced to 1900. Although not made use of, they have been tacked on the ends of the Greenwich series, and it must be understood that agreement or non-agreement with that series must not be taken too seriously. For convenience the Right Ascensions and N.P.D.'s are kept separate and treated independently of each other.

In reducing the R.A.'s a proper motion of $-0^s{\cdot}0375$ has been used, and originally the yearly results were used direct, as were also the N.P.D.'s, but finally it was decided to smooth them by taking the means of every three. Considering the nature of the observations, this appears quite legitimate, and results in having a less complicated series of dots to deal with.

These smoothed means are shown in fig. 5 (Plate 4).

The N.P.D.'s have been reduced with a proper motion of $+0''{\cdot}385$, the yearly means smoothed and laid down in fig. 6 (Plate 5).

The periodic nature of the curves both of R.A. and N.P.D. is evident, and similar to that deduced from the micrometric measures; consequently the positions and distances were converted into R.A. and N.P.D. The amplitude, however, seemed just about twice that of the transit Right Ascensions. At a venture the curve was then reduced one-half, and after reversion was fitted on to the transit Right Ascensions, and is shown by the continuous line in fig. 5, where it might well be mistaken for the curve really drawn through them.

Similarly, the N.P.D. curve deduced from the micrometric means was reduced one-half and fitted on the transit circle N.P.D.'s, as shown in fig. 6 (Plate 5).

In both cases the two sets of measures agree in a remarkable manner.

Hence it may be conceded that the real motion of the system is shown in fig. 7, where the left-hand ellipse is the apparent orbit of the principal star and the right-hand ellipse that of the fainter component.

The elements of the transit circle ellipse are:

Ω	$42^\circ\ 32'$	$e = {\cdot}500.$
γ	$47\ \ 18$	$a = 0''{\cdot}686.$
λ	$76\ \ 50$	$P = 34$ years (assumed).

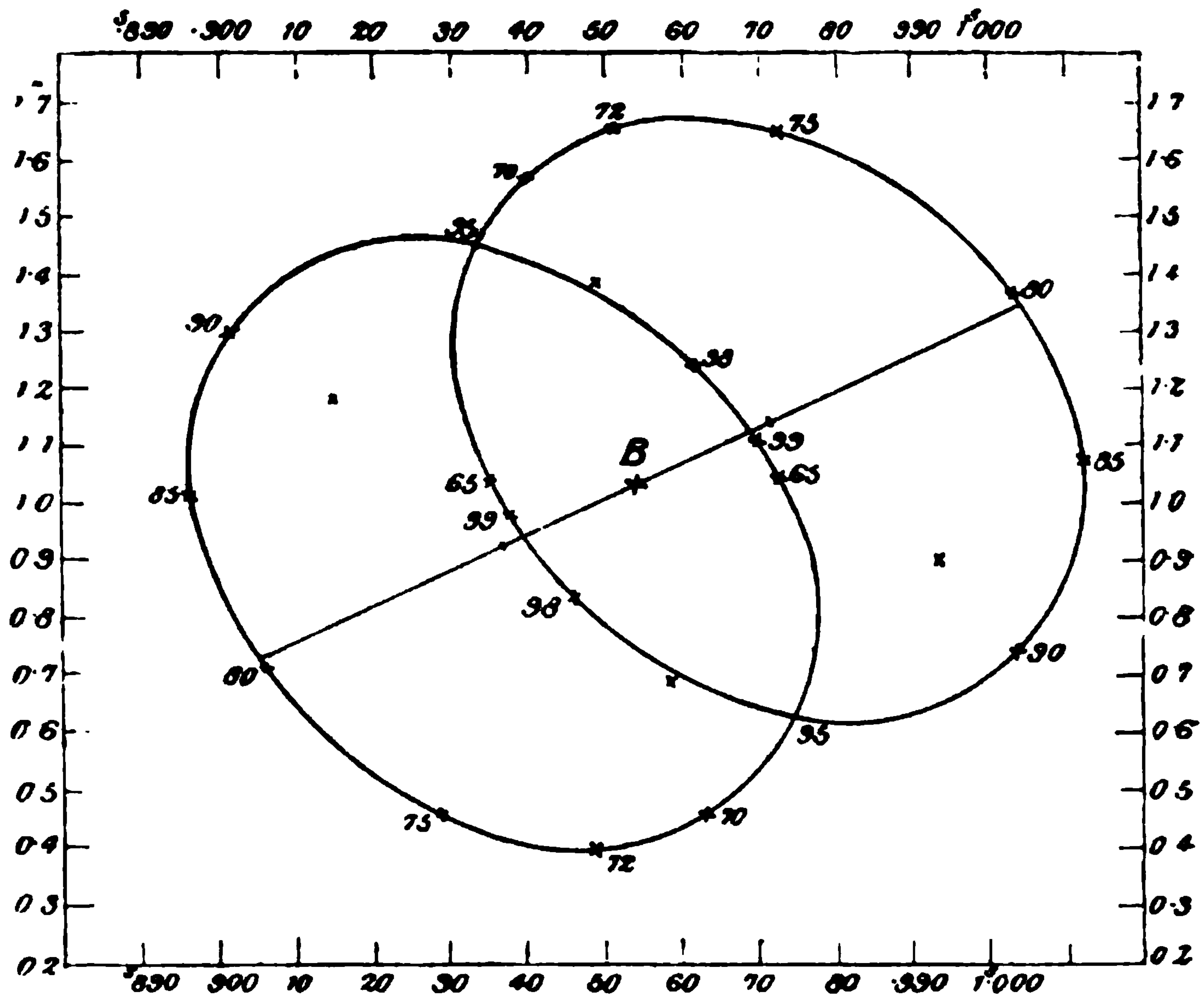


FIG. 7.—The left-hand ellipse represents the transit-circle observations from 1867 to 1869 as shown by the curves 6 and 7.
The right-hand ellipse is deduced from the first by laying off, from the several positions in that ellipse, the position-angles and distances derived from micrometric measures.

Meridian Observations collected from all Sources, reduced to 1900.

Year.	R.A.		Seconds, 1900.	Source.		N.P.D.		Seconds, 1900.	Source.	
	m	s	s			′	″	″		
1825	34	41·468	30·877	Σ		4	29·39	58·32	Σ.	
26		43·735	·886	Σ		.	.	.	.	
27		46·093	·987	Σ, Abœ			42·87	7·98	Σ, Abœ.	
28		48·33	·966		G.		50·06	8·27		G.
29		50·553	30·932	Σ, Cam.,	G.	4	56·40	7·71	Σ,	G.
30		52·919	31·039	Σ,	G.	5	4·62	9·05	Σ.	
31		55·08	30·941	Madras			8·74	6·26	Madras.	
32		57·305	·907	Madras,	G.		16·55	7·18	Munich.	
33	34	59·510	·855	Munich			24·21	7·75	Σ, Munich, G., Madras	
34	35	1·840	·927		G.		31·10	7·96		G.
35		4·030	·860	Munich			36·70	6·68	Munich.	
36		...	...				...	...		
37		8·620	·933	R.			51·30	7·54	R.	
38		10·860	·915	R.		5	58·50	7·88	R.	

Year.	R.A.	Seconds, 1900.	Source.	N.P.D.	Seconds, 1900.	Source.
	m s	s		′ ″	″	
1839	35 13·110	30·908	R., Munich	6 4·72	7·23	R., Cam., G.
40	15·310	·850	R.	10·22	5·88	R.
41	17·690	·973	R.	19·09	7·88	R.
42	19·935	·959	R., Cam.	25·86	7·79	R., Cam., Poulkova.
43	22·200	·966	R.	32·35	7·42	R., Cam.
44				39·00	7·02	Cam.
45	26·682	·888	Madras, G.	46·78	8·17	Madras, Poulkova.
46	28·938	·913	R., G.	6 53·55	8·12	R., Cam., Poulkova.
47	...	...		...	...	
48	33·367	·839	G.	7 7·50	8·45	Brussels, G.
1849	35·627	30·842	G.	7 14·07	58·14	Brussels.

Σ = W. Struve, R. = Rumker, G. = Greenwich, Cam. = Cambridge.

Greenwich Transit Circle Observations.

Year.	R.A.	No. of Obs.	Seconds, 1900.	N.P.D.	No. of Obs.	Seconds, 1900.
	m s		s	′ ″		″
1850	35 37·99	5	30·947	7 21·04	11	{ 57·70 + 1·19
1	40·12	9	·819	27·50	20	0·80
2	42·47	7	·917	34·75	30	1·22
3	44·72	15	·902	41·01	17	0·66
4	46·96	2	·880	...	...	...
5	49·28	7	·942	7 55·00	8	0·81
6	51·50	8	·892	8 2·50	13	1·51
7	53·76	5	·895	9·36	7	1·56
8	56·01	7	·886	16·15	9	1·54
9	35 58·35	6	·968	23·30	5	1·87
1860	36 0·57	5	·929	30·02	5	1·78
1	2·86	5	·971	37·03	10	2·19
2	5·09	3	·942	43·42	4	1·79
3	7·39	3	·984	49·92	3	1·50
4	9·62	5	·954	8 56·72	5	1·52
5	11·91	4	·976	9 3·39	3	1·40
6	14·17	9	·987	9·99	6	1·22
7	16·40	10	·960	16·20	6	0·94
8	18·67	11	·973	22·74	18	0·91
9	20·94	13	·985	29·68	8	1·17
1870	23·16	5	·945	36·42	6	1·04
1	25·43	3	·958	...	...	...

Year.	R.A.	No. of Obs.	Seconds, 1900.	N.P.D.	No. of Obs.	Seconds, 1900.
	m s		"	' "		"
1872	36 27·66	3	30·928	9 49·62	6	0·59
3	29·90	7	·913	9 56·62	4	0·92
4	32·22	2	·970	10 3·39	3	0·83
5	34·38	1	·871	...	...	...
6	36·65	6	·877	16·77	6	0·71
7	38·97	9	·940	23·59	7	0·28
8	41·20	7	·905	30·64	5	0·58
9	43·44	4	·893	37·19	9	0·38
1880	45·74	7	·935	44·23	8	0·69
1	47·97	9	·909	51·43	6	1·15
2	...	...	...	10 57·85	6	0·84
3	52·48	5	30·890	11 5·17	7	1·43
4	54·86	3	31·014	11·70	2	1·24
5	57·04	3	30·934	17·98	2	0·75
6	36 59·37	1	31·003	24·71	4	0·81
7	37 1·57	6	30·951	31·42	5	0·80
8	3·79	1	·906	38·08	2	0·74
9	6·06	1	·917	45·72	3	1·66
1890	8·30	7	·898	11 52·32	4	1·55
1	10·59	2	·930	12 0·02	2	2·56
2	12·86	6	·938	5·24	4	1·09
3	15·10	23	·922	12·56	16	1·74
4	17·34	22	·905	18·93	22	1·38
5	19·65	20	·950	25·66	18	1·40
6	21·88	20	·926	...	12	1·66
7	24·16	16	·939	39·19	9	1·52
8	26·44	13	·957	45·53	11	1·18
1899	28·70	31	30·955	52·00	18	0·97

Part III.

Remarks on Colour, Magnitude, Irregular Motion, &c.

The most natural cause of the opening out of the ellipse, its rotation, and the discrepancies in the period would be the duplicity of either star. While the micrometer measures were under discussion there seemed abundant evidence that such was in truth the case with the secondary star, and the idea was somewhat strengthened by its apparent variation in colour and magnitude ; but since the discussion of the meridian observations and an investigation of the colour and magnitude the evidence is all in favour of the primary being double, and this is

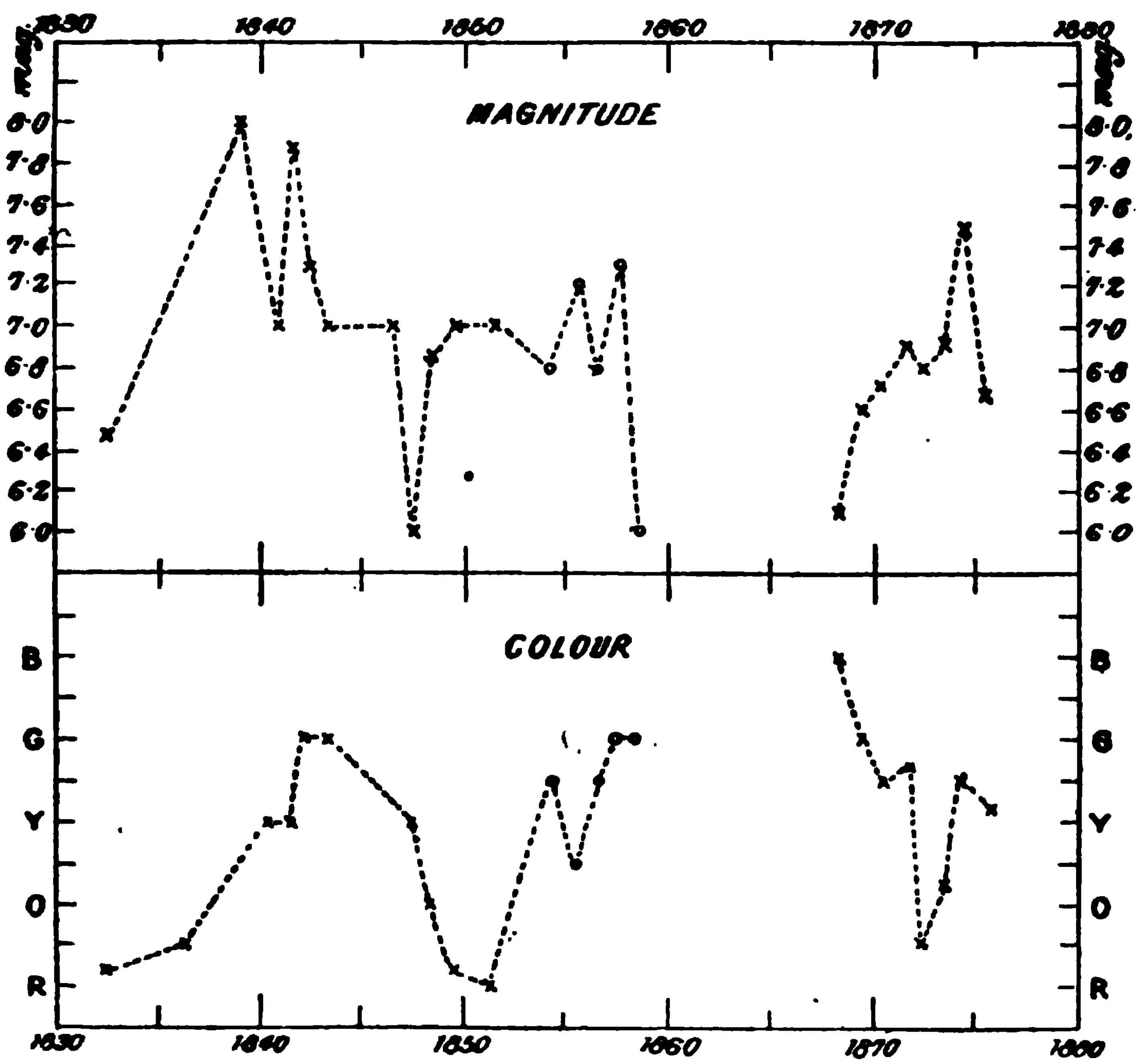
suggested, with some diffidence, as the cause of all the peculiarities of motion in the system.

The grounds upon which this suggestion is based are the wavy lines in figs. 2, 3, 5, and 6 in the first instance, and since the residuals from the meridian observations are more marked than those from the micrometric measures the duplicity is ascribed to the principal star.

The period of this component is about twelve years and the semi-major axis 0″·25.

Magnitude and Colour.

All observers agree in calling the principal star yellow and 3·0 magnitude. The evidence in the case of the small component is not so satisfactory. The personal equation of the observer, the state of the atmosphere, and the colour correction of the object-glass and eyepiece enter so largely into estimations of magnitude, and more especially colour, that the results even of two such careful observers as Dembowski and Dunér are often in conflict. If we confine ourselves to the results of Dawes as a base, and tack those of Struve on one end, and on the other the early estimations of Dembowski, followed by those of Dunér, we obtain what may possibly be a period of seventeen or eighteen years both in colour and magnitude.



To me the colour from 1895 to 1898 was dark blue, whereas it is now a decided green; and, so far as they go, these observations fall in with those just mentioned. If we accept these results, then the magnitude seems to vary from 6·5 to 7·5 and the colour from red to blue.

1826	Struve	7·0	
32	"	6·5	
33	"	...	Reddish
36	"	...	"
39	Dawes	8·0	
40	"	7·0	Yellow
41	"	7·9	"
42	"	7·3	Blue, yellow
43	"	7·0	"
46	"	7·0	
47	"	6·0	Yellow
48	"	6·9	Reddish yellow
49	"	7·0	Pale red
51	"	7·0	Red
54	Dembowski	6·8	Olive
55	"	7·2	Orange yellow
56	"	6·9	Olive
57	"	7·3	Greenish olive
58	"	6·0	Yellowish olive
68	Dunér	6·1	Blue
69	"	6·6	Green
70	"	6·7	Olive
71	"	6·9	"
72	"	6·8*	"
73	"	6·9	Orange
74	"	7·5	Olive
1875	"	7·0	"

Spectroscopic Observations.

The spectroscopic determinations of the motion in the line of sight are:—

1893 May	18,	Belopolsky *	−68	km./sec.
"	22,		−84	

* *Ast. Nach.* 133, 257.

1893 June 2,		−75 km./sec.
„ 3,		−67
„ 4.		−66
„ 14,		−64
„ 16,		−69
1897 April 29,	Campbell *	−69·1
June 14,	Newall †	−71·4
1898 May 11,	Campbell	−70·4
„ 16,	Newall	−68·4
„ 23,	Campbell	−70·0
Aug. 19,	Campbell	−70·9
1899 April 29,	Newall	−74·3

If we neglect the determination on 1893 May 22, these reduce to

1893·4	−68·0 km./sec.	= −42·2	miles/sec.
97·9	−69·9 „	= −43·4	„
98·7	−71·6 „	= −44·5	„

From these values the computed parallaxes are 0″·157 and 0″·134, which, seeing that the true anomaly varies 76°, may be regarded with more favour than one is at first disposed to show. Adopting then

0″·14 as the parallax, we obtain :
0·89 as the combined mass,
0·44 as the mass of each star,
925,000,000 miles as the mean distance apart,
2·7 miles the average velocity in orbit,
1·8 the velocity in line of sight at the node,
42·5 miles the observed velocity in line of sight at node,
44·3 „ of approach to our system,
27·9 „ velocity in line of sight due to proper motion,
8·6 „ velocity of proper motion in N.P.D.,
10·0 „ velocity of proper motion in R.A.,
31·0 „ resultant velocity in space.

It is clearly evident that great reliance cannot be placed on the parallax deduced in this way, and the figures above must be regarded as merely giving a general idea of the system. I must say that the consistency of spectroscopic measures has come as a great surprise to me, and no doubt in cases where the change of velocity is large, a fair value of the parallax could be deduced. In the present case a change of even one kilometre in $v-v_1$ has a large effect on the parallax.

* *Astrophysical Journal*, viii. 157.
† Hitherto unpublished.

1900 *December* 10.

Magnitude of Wide Companion of ζ Lyræ.
By the Rev. S. J. Johnson, M.A.

In the case of this wide object, almost one suitable for the binocular, the impressions recorded of magnitude seem singularly discordant; and if these estimations have been made with care, they seem to suggest the idea of variability with a long period.

In the *Intellectual Observer*, 1862 December, the Rev. T. Webb says, "In 1850·77 and 1865·68 with $3\frac{7}{10}$ inches, I thought the smaller star 7 and 6. It now appears as in Smyth," that is to say, magnitudes 5, $5\frac{1}{2}$.

In 1876 Plummer gives 4, $6\frac{1}{2}$, an immense difference between the components.

Even in so trustworthy a work as the *Washington Observations of Double Stars, made at the U.S. Naval Observatory*, Part ii., 1880–1891, they are given as "4 and 6."

The following are extracts from my own notes :—

"1884 September 19. Mags. 5, 6, nearly, if not quite, a whole magnitude difference. Colours, yellow, brownish-yellow.

"1887 October 10. Mags. 5, 6. Yellow, lilac-tint.

"1891 January 21. Yellow, bluish. Mags. 5, 6, or more strictly speaking, not above $\frac{3}{4}$ magn. difference.

"1897 May 21. Barely $\frac{1}{2}$ magnitude difference in the stars, the smaller somewhat bluish."

And on November 15 this year, 1900, the same impression: mags. 5, $5\frac{1}{3}$.

The fact that I know of no list of variables in which this star is included seems to make it worth while to remark on the matter.

Melplash Vicarage, Bridport:
December 10.

Observations of the Leonid Meteors of 1900 *made at the Royal Observatory, Greenwich.*

(*Communicated by the Astronomer Royal.*)

On the night of November 13–14 twenty-five meteors were observed by three observers between midnight and 5^h A.M., five of which were Leonids. The watch was occasionally interrupted by cloud. On the night of November 14–15 the effective watch was limited to two hours only (the sky clouding up completely before 3^h A.M.), and twenty meteors, of which six were Leonids, were seen by two observers. On the night of November 15–16 a watch was maintained by three observers from 11^h P.M. until $3^h\ 30^m$ A.M. (when the sky became overcast), and fifty-five meteors were observed, twenty-three of which were conformable to the *Leo* radiant. There was no appearance of a shower on any of the nights of observation.

Royal Observatory, Greenwich:
1900 *December* 29.

The Leonids 1900*: Observations at the University Observatory, Oxford.* By H. H. Turner, M.A., F.R.S., Savilian Professor.

Continuous watch was kept on the nights of November 13, 14, 15, with practically no result. On November 13 the sky clouded over at $16^h\ 35^m$; on November 14, at $13^h\ 20^m$; and on November 15 at about $13^h\ 30^m$, though there was a partial clearance about 15^h–16^h. On November 14 about eleven meteors were noticed between the hours of $11^h\ 30^m$ and 14^h, none of them *Leonids*; but no special attention was paid to these observations, the watch being kept simply for a notable display. Several cameras were ready for exposures, but of course no results were obtained.

The Leonids, 1900. *Observations made at the Radcliffe Observatory, Oxford.*

(*Communicated by the Radcliffe Observer.*)

In anticipation of a return of the Leonids this November, arrangements were made for observations, and, in view of the possibility of a dense swarm occurring, an electric cable had been laid from the tower to the chronograph, and a mechanical enumerator was also provided.

On November 11 and 12 an examination of the sky was made at intervals, but the observers failed to detect any Leonids. Much cloud prevailed.

On the night of November 13 Mr. McClellan undertook the watch from 11^h to $14^h\ 30^m$, when he was relieved by Mr. Wickham, who remained on duty till dawn.

On November 14 Mr. Robinson kept watch during the whole period from 11^h till dawn.

It was further arranged that Mr. Jenkins, who slept during these two nights at the Observatory, should, in the event of a shower of meteors, be sent to summon the Radcliffe Observer and the other members of the staff.

The observers on duty report as follows :—

Mr. McClellan.—November 13, $11^h\ 30^m$ to $14^h\ 30^m$ G.M.T. The sky was very variable, being often covered with quickly moving cloud, whilst in the East thin clouds, which remained almost stationary, concealed the radiant until 14^h; after this the "Sickle" could be seen through breaks in drift.

At $13^h\ 30^m$ a sporadic meteor crossed the constellation of *Orion* from E. to W. with a swift motion.

Mr. Wickham.—November 13, $14^h\ 30^m$ to $15^h\ 15^m$. The sky was sufficiently clear to identify all my reference stars, except those below the 4th magnitude, which were invisible, the Moon being near the radiant in the constellation *Leo*. The haze near

the horizon was thick enough to obliterate all stars below the 1st magnitude. At 15^h 15^m G.M.T. the sky clouded for fifteen minutes, then rapidly cleared, but floating clouds occasionally concealed the Moon and the radiant.

The following notes of meteors were taken :—

G.M.T. h	m	
15	44	Leonid across *Coma Berenices*, $3\frac{1}{2}$ mag. When tracking its course by means of a straight-edged wand, it had evidently proceeded from the *Leo* radiant.
15	52	Two Leonids in rapid succession passed just above δ *Leonis* ; the second was the brighter, and estimated mag. 3.
15	57	Leonid, from near *Mars*, almost perpendicularly into the haze near horizon. *Mars* was in the centre of the triangle formed by α, η, and ψ *Leonis*.
16	8	Leonid, from ζ *Leonis* upwards into *Leo Min*. Reference stars are faint here.
16	8	From *Leo* radiant down to ρ *Leonis*.
16	10	From *Leo* radiant to near ω *Ursæ Majoris*.
16	14·5	Sporadic, from near o *Ursæ Maj*., past the "Sickle," to just beyond β *Leonis*.
16	21	Leonid, from γ to δ *Leonis*.
16	27·5	Leonid, from γ *Leonis* to ξ *Ursæ Majoris*.
16	29	Leonid, from *Mars* downwards towards horizon.
16	30+	Clouds came up and obscured the whole sky.
18		Shower of rain.

Considering that moonlight, haze, and cloud were serious impediments, and that it is also probable some Leonids escaped notice whilst I was making entries in my note-book of those observed, I am of opinion that in the absence of the Moon from the radiant, and with a clear sky, I should have observed as many as during my watch last year. The meteors noted above preserved their characteristics of yellowish light, rapid motion, and a faint short trail or streak quickly fading out.

Mr. Jenkins.—November 13^d 18^h 13^m to 17^m. "I saw four meteors during breaks in cloud, the only other objects visible being the Moon, *Mars*, and *Regulus*." From a sketch made shortly afterwards, three of these appear to be Leonids, whilst the fourth is doubtful.

Mr. Robinson.—November 14^d 11^h to 12^h 30^m. Sky covered with detached masses of cloud ; stars only occasionally visible. For the next hour the clouds parted sufficiently to reveal whole constellations, principally *Taurus*, *Gemini*, *Ursæ Maj*., and *Orion* ; but only stars to mag. 4 were visible. At 12^h 50^m many faint stars were easily seen. At 13^h, sky thicker, with lunar halo, *Regulus* and *Mars* visible. At 16^h, rain till after dawn.

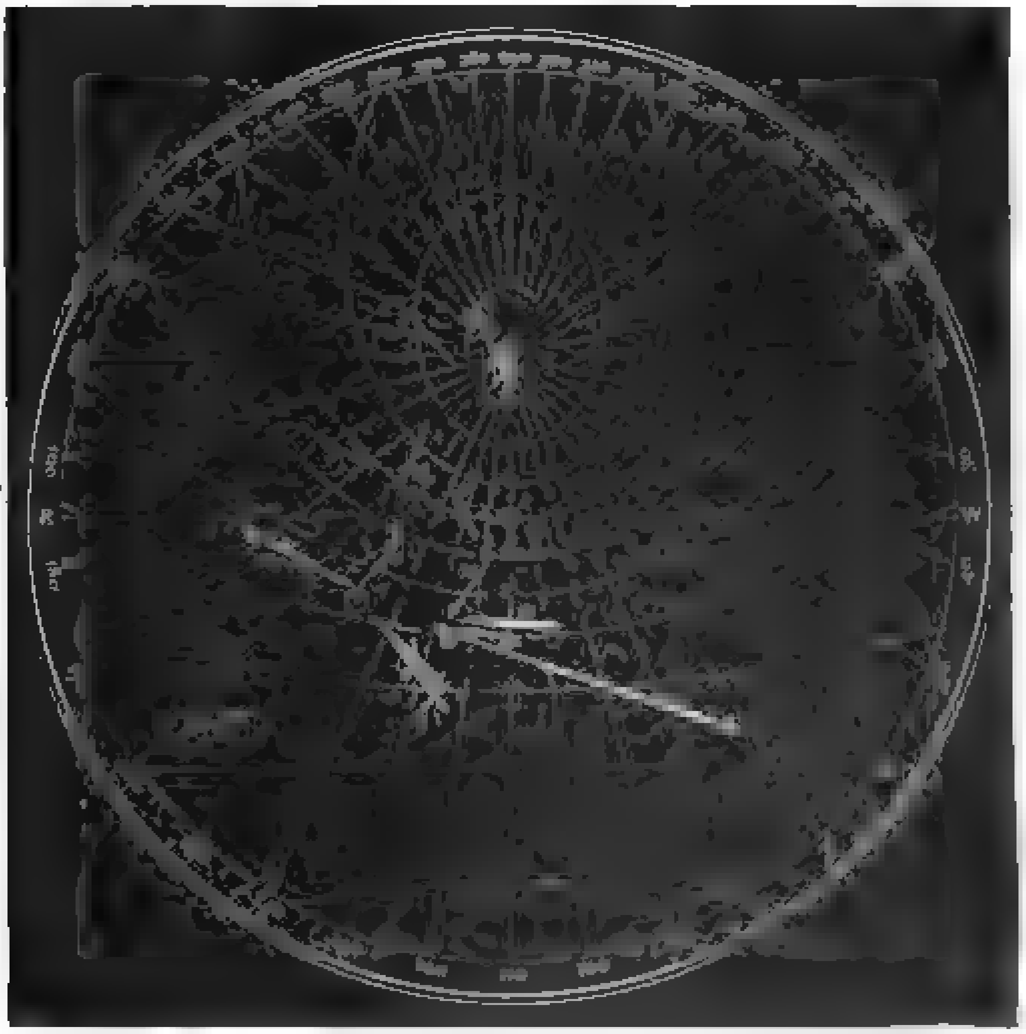
No meteors were seen during the watch ; but, owing to the

unfavourable conditions, meteors fainter than mag. 2 would hardly have been visible, except for a short interval about $12^h\ 50^m$.

On November 15 watches were kept for brief intervals, but no meteors were seen by any of the observers.

The Leonids, 1900 *November* 14 *: Observations made at Blackheath, S.E.* By E. M. Antoniadi and A. C. D. Crommelin.

The sky was laden with heavy clouds on the night of November 14 15, but the wide gaps between them were so admirably transparent that stars of the second and third magnitudes in *Canis Major* could be easily seen down to within a very few degrees of the horizon.



Fourteen meteors, of which seven were *Leonids,* were recorded in three hours' watch, from $11^h\ 45^m$ to $14^h\ 45^m$ G.M.T. Owing to the clouds it is impossible to give an horary mean of the number of *Leonids* that would have been visible at the time

with a clear sky. But there is good evidence to show that such mean could scarcely exceed three or four per hour. From $13^h\ 7^m$ to $13^h\ 47^m$ the sky was quite clear, and yet no *Leonid* was seen during this interval of 40^m.

The following table, which is completed by the annexed figure, will speak for itself :—

Meteors seen at Blackheath on 1900 *November* 14 *from* $11^h\ 45^m$ *to* $14^h\ 45^m$.

No.	Hour G.M.T.		Track. From		Track. To		Mag.	Notes.		Observer.
			α	δ	α	δ				
	h	m	°	°	°	°				
1	11	46	145	+21	125	+11	2	Moderately swift.	*Leonid.*	C.
2	12	4	168	+48	186	+44	3½	Rather slow.		A.
3	12	15	124	+11	130	+6	3	Moderately slow.		C., A.
4	12	19	195	+77	222	+67	5	Swift.		A.
5	12	19½	125	+20	71	+4	3	Swift.	*Leonid.*	C.
6	12	23	140	+19	123	+8	3½	Rather slow.	*Leonid.*	C., A.
7	13	2	152	+26	173	+27	2	Rather slow.	*Leonid.*	C.
8	13	4	103	+84	244	+81	1	Swift.		A.
9	13	42	124	+44	136	+53	4	Swift; perhaps curved.		A.
10	13	47	124	+23	96	+22	> ♃	Swift; streak.	*Leonid.*	A.
11	13	47½	149	+29	148	+40	5½	Swift.	*Leonid.*	A.
12	13	57	117	+41	127	+24	3	Swift.		A.
13	13	59	108	+20	130	+21	3	Swift.		A.
14	14	5	157	+47	169	+65	4	Very swift.	*Leonid.*	A.

No 10 was a grand red globe, brighter than *Jupiter*, and leaving an intense emerald green trail, lasting for $1\frac{1}{2}^s$.

By producing backwards the seven *Leonid* tracks we obtain a mean radiant towards

$$\alpha = 149^\circ\ ;\ \delta = +23^\circ.$$

The radiant of Nos. 6 and 7 was distinctly a little higher ; at

$$\alpha = 149^\circ\ ;\ \delta = +25^\circ.$$

This brief account will suffice to show that, in perfect harmony with the investigations of Drs. Downing and Stoney, the recent display of the *Leonids* was an insignificant one, falling far below an ordinary *Perseid* shower.

Watch for the Leonids 1900, *at Markree Observatory.*
By F. W. Henkel, B.A.

Arrangements were made for watches during the nights of November 14, 15, and 16, though in view of the usually unfavourable atmospheric conditions at this time of the year, and the probability of our missing an encounter with a rich part of the stream (alluded to by Mr. Denning in *Nature* for November 8), there arose a feeling of uncertainty as to the result.

On the first night (14–15) rain and unusually high wind continued almost the whole time, so that the sky was completely overcast.

The second night (15–16) was at first somewhat clearer, but rain fell about midnight, and the sky was almost completely hidden by clouds during the remainder of the night. No *Leonids* were seen during the time the watching continued (up to 1 A.M.).

November 16 was a fine day on the whole, and towards midnight the sky became very clear, so that hopes were entertained that something might be seen at last if anything was to be seen at all of the meteors. The sky was watched till about 1 A.M. on the morning of the 17th, when it became overcast in the east, and again at 4 A.M. on the same morning, at which time, however, there were a good many clouds.

Two meteors were seen about 0·30 A.M. (D.M.T.) on the early morning of the 17th, one, fairly bright, with path ending near ζ *Geminorum*, the other, fainter, near *Regulus*. At 4 A.M. no meteors could be seen, though a careful watch was made for some time.

Markree Observatory, Collooney, Ireland:
1900 *November* 18.

Ephemeris for Physical Observations of

Greenwich Noon.	P.	L—O.	B.	Apparent Diameter. Equat. 2a.	Defect.	Polar 2b.	d.	Q.	B'.
1901.	°	°	°	"	"	"	°	°	°
Jan. 17	359·325	134·144	−2·268	32·62	0·06	30·52	4·88	270·71	−2·42
19	359·124	134·573	2·259	32·70	·07	30·59	5·15	270·50	2·41
21	358·925	135·001	2·250	32·79	·07	30·68	5·41	270·30	2·41
23	358·728	135·424	2·241	32·88	·08	30·76	5·67	270·10	2·40
25	358·532	135·844	2·232	32·98	·09	30·85	5·93	269·90	2·39
27	358·338	136·260	−2·223	33·08	·10	30·95	6·18	269·70	−2·38
29	358·147	136·671	2·214	33·19	·10	31·05	6·43	269·51	2·37
31	357·957	137·078	2·205	33·30	·11	31·15	6·67	269·31	2·36
Feb. 2	357·769	137·482	2·196	33·41	·12	31·26	6·91	269·12	2·35
4	357·583	137·880	2·187	33·53	·13	31·37	7·15	268·92	2·34
6	357·400	138·273	−2·178	33·66	·14	31·49	7·38	268·74	−2·33
8	357·219	138·661	2·169	33·79	·15	31·61	7·61	268·55	2·32
10	357·041	139·044	2·160	33·92	·16	31·74	7·83	268·36	2·31
12	356·865	139·423	2·151	34·06	·17	31·87	8·04	268·18	2·30
14	356·692	139·795	2·142	34·21	·18	32·00	8·25	268·01	2·29
16	356·523	140·161	−2·133	34·35	·19	32·14	8·46	267·84	−2·28
18	356·356	140·521	2·124	34·51	·20	32·28	8·66	267·67	2·27
20	356·193	140·874	2·115	34·66	·21	32·43	8·85	267·50	2·26
22	356·033	141·221	2·106	34·83	·22	32·58	9·04	267·33	2·25
24	355·877	141·560	2·097	34·99	·23	32·74	9·22	267·18	2·24
26	355·723	141·893	−2·089	35·16	·24	32·90	9·39	267·02	−2·23
28	355·573	142·220	2·080	35·34	·25	33·07	9·55	266·86	2·22
Mar. 2	355·427	142·540	2·072	35·52	·25	33·23	9·70	266·71	2·21
4	355·283	142·851	2·064	35·71	·26	33·41	9·85	266·56	2·21
6	355·142	143·155	2·056	35·90	·27	33·58	9·99	266·42	2·20
8	355·008	143·451	−2·048	36·09	·28	33·76	10·13	266·28	−2·19
10	354·878	143·738	2·040	36·29	·29	33·95	10·25	266·15	2·18
12	354·751	144·016	2·032	36·49	·30	34·14	10·36	266·02	2·17
14	354·627	144·285	2·024	36·70	·31	34·33	10·46	265·89	2·16
16	354·506	144·545	2·016	36·91	·31	34·53	10·56	265·76	2·15
18	354·393	144·797	−2·008	37·12	·32	34·73	10·65	265·65	−2·15
20	354·283	145·039	2·001	37·34	·33	34·94	10·73	265·54	2·14
22	354·179	145·272	1·994	37·57	·33	35·15	10·80	265·44	2·13
24	354·078	145·494	1·987	37·79	·34	35·36	10·86	265·33	2·12
26	353·980	145·707	−1·980	38·02	0·34	35·58	10·91	265·22	−2·12

Jupiter, 1901. By A. C. D. Crommelin.

Greenwich Noon.		Longitude of ♃'s Central Meridian. 877°·90 I.	870°·27 II.	Corr. for Phase.	Light-time.	A–O.	B.
1901.		°	°	°	m	°	°
Jan.	17	43·60	31·21	+0·10	50·932	129·262	−2·377
	19	359·04	331·39	·12	50·802	129·423	
	21	314·49	271·58	·13	50·666	129·585	
	23	269·96	211·79	·14	50·522	129·747	
	25	225·43	152·00	·15	50·374	129·909	
	27	180·92	92·23	+0·17	50·219	130·071	−2·349
	29	136·41	32·46	·18	50·058	130·233	
	31	91·91	332·70	·19	49·890	130·396	
Feb.	2	47·41	272·94	·21	49·717	130·558	
	4	2·92	213·19	·22	49·539	130·720	
	6	318·43	153·44	+0·24	49·355	130·882	−2·321
	8	273·95	93·70	·25	49·165	131·045	
	10	229·49	33·98	·27	48·971	131·207	
	12	185·03	334·26	·28	48·770	131·370	
	14	140·58	274·55	·30	48·565	131·532	
	16	96·15	214·85	+0·31	48·358	131·645	−2·293
	18	51·72	155·16	·33	48·141	131·858	
	20	7·31	95·49	·34	47·923	132·020	
	22	322·90	35·82	·36	47·700	132·183	
	24	278·50	336·16	·37	47·472	132·345	
	26	234·10	276·49	+0·38	47·241	132·508	−2·263
	28	189·72	216·85	·40	47·006	132·671	
Mar.	2	145·35	157·22	·41	46·767	132·834	
	4	100·98	97·59	·42	46·525	132·997	
	6	56·62	37·97	·44	46·280	133·160	
	8	12·28	338·37	+0·45	46·030	133·324	−2·234
	10	327·95	278·78	·46	45·778	133·487	
	12	283·63	219·20	·47	45·525	133·650	
	14	239·32	159·63	·48	45·268	133·813	
	16	195·02	100·07	·49	45·009	133·976	
	18	150·72	40·50	+0·49	44·749	134·140	−2·204
	20	106·43	340·95	·50	44·486	134·303	
	22	62·16	281·42	·51	44·233	134·406	
	24	17·90	221·90	·51	43·957	134·629	
	26	333·65	162·39	+0·52	43·690	134·793	

Greenwich Noon.	P.	L−O.	B.	Apparent Diameter. Equat. 2a.	Defect.	Polar 2b.	d.	Q.	B′.
1901.	°	°	°	″	″	″	°	°	°
Mar. 28	353.889	145.909	−1.973	38.26	0.35	35.79	10.95	265.13	−2.11
30	353.803	146.101	1.967	38.49	.35	36.01	10.98	265.04	2.10
Apr. 1	353.721	146.282	1.960	38.73	.36	36.24	10.99	264.95	2.10
3	353.644	146.452	1.954	38.98	.36	36.47	11.00	264.87	2.09
5	353.572	146.611	1.948	39.23	.36	36.70	10.99	264.79	2.08
7	353.505	146.758	−1.942	39.48	.36	36.93	10.98	264.72	−2.08
9	353.443	146.895	1.936	39.73	.36	37.17	10.95	264.66	2.07
11	353.386	147.020	1.931	39.98	.36	37.41	10.91	264.60	2.06
13	353.335	147.134	1.926	40.24	.36	37.65	10.86	264.54	2.06
15	353.290	147.235	1.921	40.50	.36	37.89	10.80	264.49	2.05
17	353.250	147.324	−1.916	40.76	.36	38.13	10.73	264.45	−2.05
19	353.215	147.401	1.911	41.02	.35	38.37	10.64	264.41	2.04
21	353.186	147.466	1.907	41.28	.35	38.62	10.54	264.38	2.04
23	353.163	147.517	1.903	41.54	.34	38.87	10.43	264.35	2.03
25	353.145	147.557	1.899	41.80	.34	39.11	10.31	264.33	2.03
27	353.132	147.584	−1.895	42.07	.33	39.35	10.17	264.32	−2.03
29	353.127	147.599	1.892	42.33	.32	39.60	10.02	264.31	2.02
May 1	353.126	147.601	1.889	42.59	.31	39.84	9.86	264.31	2.02
3	353.130	147.591	1.886	42.85	.30	40.09	9.68	264.31	2.02
5	353.139	147.568	1.884	43.10	.29	40.33	9.49	264.32	2.01
7	353.154	147.532	−1.881	43.36	.28	40.57	9.29	264.32	−2.01
9	353.175	147.485	1.879	43.61	.27	40.81	9.08	264.34	2.01
11	353.202	147.424	1.877	43.86	.26	41.04	8.86	264.36	2.01
13	353.235	147.352	1.875	44.11	.25	41.27	8.62	264.39	2.00
15	353.273	147.267	1.873	44.35	.24	41.50	8.37	264.42	2.00
17	353.316	147.170	−1.871	44.59	.22	41.72	8.11	264.46	−2.00
19	353.365	147.061	1.870	44.82	.21	41.94	7.84	264.49	2.00
21	353.419	146.940	1.869	45.05	.19	42.15	7.55	264.54	2.00
23	353.478	146.808	1.868	45.27	.18	42.36	7.25	264.59	2.00
25	353.542	146.665	1.867	45.48	.16	42.56	6.94	264.64	1.99
27	353.610	146.512	−1.866	45.69	0.14	42.75	6.63	264.70	−1.99
29	353.684	146.348	1.866	45.89	0.13	42.94	6.30	264.76	1.99
31	353.762	146.175	1.865	46.08	.12	43.12	5.96	264.83	1.99
June 2	353.844	145.993	1.865	46.27	.11	43.29	5.61	264.90	1.99
4	353.931	145.802	1.865	46.44	.10	43.45	5.25	264.98	1.99
6	354.022	145.601	−1.866	46.60	.09	43.60	4.89	265.06	−1.99
8	354.116	145.393	1.866	46.75	.07	43.74	4.52	265.14	1.99
10	354.215	145.176	−1.866	46.89	0.06	43.87	4.13	265.23	−1.99

Greenwich Noon. 1901.		Longitude of ♃'s Central Meridian. 877°·90 I.	870°·27 II.	Corr. for Phase.	Light-time.	A – O.	*B.*
		°	°	°	m	°	°
Mar.	28	289·41	102·89	+0·52	43·422	134·956	–2·173
	30	245·18	43·40	·53	43·155	135·120	
Apr.	1	200·96	343·92	·53	42·886	135·283	
	3	156·75	284·45	·53	42·618	135·447	
	5	112·56	224·99	·53	42·350	135·610	
	7	68·38	165·54	+0·53	42·083	135·774	–2·142
	9	24·21	106·11	·52	41·816	135·938	
	11	340·05	46·69	·52	41·550	136·102	
	13	295·90	347·28	·52	41·285	136·266	
	15	251·76	287·88	·51	41·022	136·429	
	17	207·62	228·48	+0·50	40·762	136·593	–2·110
	19	163·50	169·10	·49	40·503	136·757	
	21	119·39	109·73	·48	40·246	136·921	
	23	75·29	50·37	·47	39·992	137·085	
	25	31·20	351·02	·46	39·741	137·249	
	27	347·13	291·68	+0·45	39·494	137·413	–2·078
	29	303·07	232·36	·44	39·250	137·577	
May	1	259·02	173·05	·42	39·010	137·743	
	3	214·97	113·74	·41	38·773	137·907	
	5	170·93	54·44	·39	38·539	138·070	
	7	126·91	355·15	+0·37	38·311	138·234	–2·045
	9	82·89	295·87	·36	38·089	138·398	
	11	38·88	236·60	·34	37·873	138·562	
	13	354·88	177·34	·32	37·664	138·727	
	15	310·89	118·09	·30	37·458	138·891	
	17	266·91	58·85	+0·29	37·255	139·056	–2·013
	19	222·94	359·62	·27	37·061	139·220	
	21	178·98	300·40	·25	36·874	139·384	
	23	135·02	241·18	·23	36·694	139·549	
	25	91·07	181·97	·21	36·522	139·715	
	27	47·12	122·75	+0·19	36·357	139·880	–1·980
	29	3·18	63·55	·17	36·197	140·044	
	31	319·24	4·35	·16	36·048	140·209	
June	2	275·31	305·16	·14	35·906	140·373	
	4	231·38	245·97	·12	35·773	140·537	
	6	187·46	186·79	+·10	35·649	140·702	–1·946
	8	143·54	127·61	·09	35·532	140·867	
	10	99·62	68·43	+·07	35·424	141·032	

Greenwich Noon.	P.	L—O.	B.	Apparent Diameter. Equat. 2a.	Defect.	Polar 2b.	d.	Q.	B′.
1901.	°	°	°	″	″	″	°	°	°
June 12	354·316	144·953	−1·866	47·03	0·05	44·00	3·74	265·32	1·99
14	354·421	144·722	1·867	47·15	·04	44·12	3·35	265·42	2·00
16	354·527	144·487	1·867	47·25	·03	44·21	2·95	265·51	−2·00
18	354·637	144·247	1·867	47·35	·02	44·30	2·54	265·58	2·00
20	354·750	144·002	1·868	47·43	·02	44·38	2·13	265·62	2·00
22	354·864	143·752	−1·868	47·50	·01	44·44	1·72	265·63	2·00
24	354·979	143·501	1·869	47·56	·01	44·49	1·31	265·55	2·00
26	355·093	143·247	1·869	47·60	·00	44·53	0·89	265·	−2·00
28	355·209	142·992	1·869	47·63	·00	44·56	0·47	265·	2·00
30	355·327	142·735	1·870	47·64	·00	44·57	0·04	257·	2·00
July 2	355·446	142·478	−1·870	47·65	·00	44·58	0·38	87·	2·00
4	355·564	142·222	1·871	47·65	·00	44·58	0·80	87·	2·00
6	355·680	141·968	1·871	47·62	·00	44·55	1·22	87·	−2·00
8	355·795	141·715	1·871	47·58	·01	44·52	1·64	87·05	2·00
10	355·911	141·464	1·871	47·53	·02	44·47	2·06	87·10	2·00
12	356·025	141·217	−1·871	47·47	·02	44·41	2·47	87·16	2·00
14	356·137	140·974	1·871	47·39	·03	44·34	2·88	87·24	2·00
16	356·247	140·736	1·871	47·30	·04	44·25	3·28	87·32	−2·00
18	356·354	140·504	1·870	47·20	·05	44·16	3·68	87·41	2·00
20	356·460	140·278	1·870	47·09	·06	44·06	4·07	87·50	2·00
22	356·562	140·057	−1·869	46·97	·07	43·94	4·45	87·58	2·00
24	356·660	139·845	1·869	46·84	·08	43·81	4·83	87·67	2·00
26	356·755	139·641	1·868	46·69	·09	43·68	5·20	87·75	−2·00
28	356·845	139·445	1·867	46·53	·11	43·53	5·56	87·83	2·00
30	356·932	139·258	1·865	46·37	·12	43·38	5·91	87·90	1·99
Aug. 1	357·015	139·080	−1·864	46·19	·14	43·21	6·26	87·97	1·99
3	357·093	138·911	1·862	46·01	·15	43·04	6·60	88·04	1·99
5	357·166	138·754	1·861	45·82	·17	42·86	6·92	88·11	−1·99
7	357·234	138·606	1·859	45·62	·18	42·68	7·23	88·19	1·99
9	357·298	138·470	1·857	45·41	·20	42·49	7·54	88·26	1·98
11	357·356	138·344	−1·855	45·20	·21	42·29	7·83	88·32	1·98
13	357·410	138·230	1·853	44·98	·23	42·08	8·10	88·37	1·98
15	357·457	138·128	1·851	44·75	·24	41·87	8·37	88·41	−1·98
17	357·499	138·039	1·848	44·52	·25	41·66	8·63	88·45	1·97
19	357·535	137·960	1·846	44·29	·26	41·44	8·87	88·48	1·97
21	357·565	137·895	−1·843	44·05	·28	41·22	9·11	88·51	1·97
23	357·590	137·841	1·840	43·81	·29	40·99	9·33	88·54	1·97
25	357·609	137·801	−1·837	43·56	0·30	40·76	9·54	88·55	−1·96

Greenwich Noon.		Longitude of ♃'s Central Meridian. 877°·90 I.	870°·27 II.	Corr. for Phase.	Light-time.	A−O.	B.
1901.		°	°	°	m	°	°
June	12	55·70	9·25	+0·06	35·324	141·197	
	14	11·79	310·08	·05	35·234	141·363	
	16	327·88	250·90	·04	35·155	141·528	−1·912
	18	283·96	191·72	·03	35·083	141·693	
	20	240·04	132·54	·02	35·022	141·858	
	22	196·12	73·36	+ 01	34·971	142·023	
	24	152·20	14·18	+0·01	34·931	142·189	
	26	108·27	315·00	·00	34·898	142·354	−1·877
	28	64·34	255·81	00	34·877	142·519	
	30	20·41	196·62	·00	34·865	142·685	
July	2	336·47	137·42	·00	34·862	142·850	
	4	292·52	78·21	·00	34·870	143·016	
	6	248·56	18·99	−0·01	34·886	143·181	−1·841
	8	204·59	319·76	·01	34·914	143·347	
	10	160·61	260·52	·02	34·950	143·513	
	12	116·63	201·28	− ·03	34·996	143·679	
	14	72·64	142·03	·04	35·052	143·845	
	16	28·65	82·78	0·05	35·117	144·011	−1·806
	18	344·65	23·52	·06	35·193	144·177	
	20	300·63	324·24	·07	35·278	144·343	
	22	256·59	264·94	− ·09	35·371	144·509	
	24	212·53	205·62	·10	35·473	144·675	
	26	168·46	146·29	0·12	35·584	144·841	−1·770
	28	124·38	86·95	·13	35·703	145·007	
	30	80·29	27·60	·15	35·830	145·173	
Aug.	1	36·19	328·24	− ·17	35·965	145·340	
	3	352·07	268·86	·19	36·108	145·506	
	5	307·94	209·47	0·21	36·259	145·673	−1·733
	7	263·80	150·07	·23	36·418	145·839	
	9	219·64	90·65	·25	36·584	146·006	
	11	175·46	31·21	− ·27	36·756	146·172	
	13	131·26	331·75	·29	36·935	146·339	
	15	87·04	272·28	0·30	37·121	146·505	−1·696
	17	42·81	212·79	·32	37·313	146·672	
	19	358·56	153·28	·34	37·511	146·839	
	21	314·30	93·76	− ·36	37·714	147·006	
	23	270·03	34·23	·38	37·923	147·172	
	25	225·74	334·69	−0·39	38·137	147·339	−1·659

Greenwich Noon.	P.	L−O.	B.	Apparent Diameter. Equat. 2a.	Defect.	Polar 2b.	d.	Q.	B′.
1901.	°	°	°	″	″	″	°	°	°
Aug. 27	357.622	137.773	−1.834	43.31	0.31	40.52	9.73	88.56	−1.96
29	357.629	137.757	1.830	43.06	.32	40.29	9.91	88.57	1.96
31	357.630	137.755	1.827	42.81	.33	40.05	10.08	88.57	1.95
Sept. 2	357.625	137.764	1.823	42.56	.34	39.82	10.24	88.56	1.95
4	357.615	137.787	1.819	42.30	.35	39.58	10.38	88.56	1.94
6	357.599	137.822	−1.815	42.05	.35	39.35	10.51	88.55	−1.94
8	357.577	137.870	1.811	41.79	.36	39.11	10.63	88.53	1.94
10	357.549	137.931	1.806	41.54	.36	38.87	10.74	88.50	1.93
12	357.514	138.004	1.802	41.29	.37	38.64	10.83	88.46	1.93
14	357.474	138.089	1.797	41.03	.37	38.40	10.91	88.42	1.92
16	357.429	138.187	−1.792	40.78	.37	38.16	10.98	88.39	−1.92
18	357.378	138.297	1.787	40.53	.37	37.92	11.04	88.34	1.91
20	357.321	138.418	1.782	40.28	.38	37.69	11.09	88.28	1.90
22	357.258	138.551	1.777	40.04	.38	37.46	11.13	88.22	1.90
24	357.190	138.697	1.771	39.79	.38	37.23	11.15	88.15	1.89
26	357.117	138.854	−1.765	39.55	.37	37.00	11.16	88.09	−1.89
28	357.039	139.020	1.759	39.31	.37	36.78	11.16	88.01	1.88
30	356.956	139.200	1.753	39.07	.37	36.56	11.15	87.93	1.87
Oct. 2	356.868	139.388	1.747	38.84	.36	36.34	11.12	87.85	1.87
4	356.775	139.589	1.740	38.62	.36	36.13	11.09	87.77	1.86
6	356.677	139.800	−1.733	38.39	.36	35.92	11.05	87.69	−1.85
8	356.574	140.021	1.726	38.17	0.35	35.71	10.99	87.60	1.84
10	356.466	140.252	1.718	37.95	.35	35.50	10.92	87.51	1.84
12	356.353	140.494	1.711	37.73	.34	35.30	10.85	87.41	1.83
14	356.237	140.745	1.704	37.52	.33	35.10	10.77	87.31	1.82
16	356.116	141.006	−1.696	37.31	.32	34.91	10.68	87.21	−1.81
18	355.991	141.276	1.688	37.11	.32	34.72	10.58	87.11	1.80
20	355.862	141.555	1.680	36.91	.31	34.53	10.47	87.00	1.79
22	355.729	141.843	1.672	36.71	.30	34.35	10.35	86.89	1.79
24	355.593	142.139	1.664	36.52	.29	34.17	10.22	86.78	1.78
26	355.453	142.444	−1.655	36.33	.28	34.00	10.08	86.66	−1.77
28	355.307	142.756	1.646	36.15	.27	33.83	9.94	86.54	1.76
30	355.159	143.077	1.637	35.97	.26	33.66	9.79	86.41	1.75
Nov. 1	355.008	143.404	1.628	35.80	.25	33.50	9.53	86.28	1.74
3	354.855	143.740	1.619	35.63	.24	33.34	9.39	86.14	1.73
5	354.698	144.084	−1.609	35.47	.23	33.19	9.24	86.00	−1.72
7	354.537	144.434	1.599	35.31	.22	33.04	9.08	85.86	1.71
9	354.373	144.790	−1.589	35.16	0.21	32.89	8.91	85.71	−1.70

Greenwich Noon.		Longitude of ♃'s Central Meridian. 877°·90 I.	870°·27 II.	Corr. for Phase.	Light-time.	A−O.	*B.*
1901.		°	°	°	m	°	°
Aug.	27	181·44	275·13	−0·41	38·355	147·506	
	29	137·12	215·55	·43	38·577	147·673	
	31	92·78	155·95	·44	38·804	147·840	
Sept.	2	48·43	96·34	·46	39·035	148·007	
	4	4·07	36·72	·47	39·270	148·174	−1·621
	6	319·70	337·09	−0·48	39·508	148·341	
	8	275·31	277·44	·49	39·748	148·507	
	10	230·90	217·77	·50	39·990	148·674	
	12	186·47	158·08	·51	40·235	148·840	
	14	142·03	98·38	·52	40·483	149·007	−1·583
	16	97·58	38·67	−0·53	40·734	149·174	
	18	53·12	338·95	·53	40·985	149·340	
	20	8·64	279·21	·54	41·237	149·507	
	22	324·15	219·46	·54	41·490	149·674	
	24	279·65	159·71	·54	41·744	149·841	−1·544
	26	235·14	99·94	0·54	41·999	150·008	
	28	190·62	40·16	·54	42·255	150·175	
	30	146·09	340·37	·54	42·511	150·341	
Oct.	2	101·54	280·56	·54	42·766	150·508	
	4	56·98	220·75	·54	43·020	150·675	−1·504
	6	12·41	160·92	−0·53	43·273	150·842	
	8	327·83	101·08	·53	43·526	151·010	
	10	283·25	41·24	·52	43·778	151·178	
	12	238·66	341·39	·51	44·028	151·346	
	14	194·06	281·53	·50	44·276	151·514	−1·464
	16	149·45	221·66	−0·50	44·522	151·682	
	18	104·83	161·78	·49	44·766	151·850	
	20	60·20	101·89	·48	45·008	152·018	
	22	15·57	42·00	·47	45·248	152·186	
	24	330·93	342·11	·45	45·485	152·354	−1·424
	26	286·29	282·21	−0·44	45·718	152·522	
	28	241·64	222·30	·43	45·948	152·691	
	30	196·98	162·38	·42	46·175	152·859	
Nov.	1	152·31	102·45	·40	46·399	153·028	
	3	107·63	42·52	·38	46·620	153·196	−1·383
	5	62·95	342·58	−0·37	46·836	153·365	
	7	18·27	282·64	·36	47·048	153·534	
	9	333·59	222·70	−0·34	47·255	153·702	

Greenwich Noon.	P.	L—O.	B.	Apparent Diameter. Equat. 2a.	Defect.	Polar 2b.	d.	Q.	B'.
1901.	°	°	°	"	"	"	°	°	°
Nov. 11	354·208	145·154	−1·580	35·01	·20	32·75	8·72	85·57	−1·69
13	354·040	145·525	1·570	34·86	·19	32·61	8·52	85·42	1·68
15	353·869	145·901	1·559	34·72	·18	32·48	8·31	85·27	1·67
17	353·695	146·284	1·548	34·58	·17	32·35	8·10	85·12	1·65
19	353·519	146·671	1·537	34·45	·16	32·23	7·88	84·97	1·64
21	353·341	147·065	−1·526	34·32	·15	32·11	7·65	84·82	−1·63
23	353·162	147·464	1·515	34·20	·14	32·00	7·42	84·67	1·62
25	352·981	147·869	1·503	34·08	·13	31·89	7·19	84·52	1·61
27	352·797	148·278	1·491	33·97	·13	31·78	6·95	84·37	1·59
29	352·611	148·692	1·479	33·86	·12	31·68	6·70	84·22	1·58
Dec. 1	352·424	149·110	−1·467	33·76	·11	31·58	6·45	84·07	−1·57
3	352·237	149·533	1·455	33·66	·10	31·49	6·20	83·93	1·55
5	352·048	149·960	1·442	33·57	·09	31·40	5·94	83·78	1·54
7	351·857	150·391	1·429	33·48	·08	31·32	5·68	83·64	1·52
9	351·666	150·825	1·416	33·39	·08	31·24	5·41	83·49	1·51
11	351·473	151·263	1·403	33·31	·07	31·16	5·14	83·34	1·50
13	351·280	151·705	−1·389	33·23	0·06	31·09	4·87	83·19	−1·48

The following is a list of the Greenwich Mean times when the Zero meridians of the two adopted systems cross the centre of the illuminated disc :—

System I.

G.M.T. 1901.	d	h	m	G.M.T. 1901.	d	h	m	G.M.T. 1901.	d	h	m	G.M.T. 1901.	d	h	m
Jan.	17	8	38·92	Jan.	23	12	18·09	Jan.	29	15	57·11	Feb.	4	19	36·04
		18	29·54			22	8·70		30	1	47·71		5	5	26·63
	18	4	20·16		24	7	59·31			11	38·31			15	17·22
		14	10·77			17	49·91			21	28·91		6	1	7·81
	19	0	1·39		25	3	40·51		31	7	19·51			10	58·40
		9	52·01			13	31·11			17	10·11			20	48·99
		19	42·62			23	21·71	Feb.	1	3	0·71		7	6	39·58
	20	5	33·23		26	9	12·31			12	51·31			16	30·17
		15	23·84			19	2·91			22	41·91		8	2	20·76
	21	1	14·45		27	4	53·51		2	8	32·50			12	11·35
		11	5·06			14	44·11			18	23·09			22	1·94
		20	55·66		28	0	34·71		3	4	13·68		9	7	52·52
	22	6	46·26			10	25·31			14	4·27			17	43·10
		16	36·87			20	15·91			23	54·86		10	3	33·68
	23	2	27·48		29	6	6·51		4	9	45·45			13	24·26

Greenwich Noon.	Longitude of ♃'s Central Meridian. 877°·90 I.	870°·27 II.	Corr. for Phase.	Light-time.	A−O.	B.
1901.	°	°	°	m	°	°
Nov. 11	288·91	162·76	−0·33	47·458	153·871	
13	244·22	102·81	·32	47·657	154·039	−1·343
15	199·52	42·85	·30	47·851	154·208	
17	154·82	342·89	·29	48·040	154·377	
19	110·12	282·93	·27	48·224	154·546	
21	65·42	222·97	−0·26	48·402	154·714	
23	20·72	163·02	·24	48·575	154·883	−1·303
25	336·01	103·05	·23	48·743	155·052	
27	291·30	43·08	·21	48·906	155·222	
29	246·59	343·11	·19	49·063	155·391	
Dec. 1	201·88	283·14	−0·18	49·214	155·559	
3	157·17	223·17	·17	49·359	155·728	−1·262
5	112·46	163·20	·15	49·498	155·898	
7	67·75	103·23	·14	49·631	156·067	
9	23·04	43·26	·13	49·759	156·237	
11	338·33	343·29	·12	49·880	156·406	
13	293·61	283·32	−0·10	49·993	156·575	−1·221

System I.

G.M.T. 1901. d	h	m	G.M.T. 1901. d	h	m	G.M.T. 1901. d	h	m	G.M.T. 1901. d	h	m
Feb. 10	23	14·84	Feb. 18	8	25·21	Feb. 25	17	35·35	Mar. 5	2	45·32
11	9	5·42		18	15·78	26	3	25·91		12	35·86
	18	56·01	19	4	6·35		13	16·47		22	26·41
12	4	46·59		13	56·91		23	7·03	6	8	16·96
	14	37·17		23	47·48	27	8	57·59		18	7·50
13	0	27·75	20	9	38·04		18	48·13	7	3	58·05
	10	18·33		19	28·61	28	4	38·68		13	48·60
	20	8·91	21	5	19·17		14	29·24		23	39·14
14	5	59·48		15	9·74	Mar. 1	0	19·80	8	9	29·68
	15	50·05	22	1	0·30		10	10·35		19	20·22
15	1	40·62		10	50·87		20	0·90	9	5	10·76
	11	31·19		20	41·43	2	5	51·46		15	1·30
	21	21·76	23	6	32·00		15	42·01	10	0	51·84
16	7	12·33		16	22·56	3	1	32·56		10	42·38
	17	2·91	24	2	13·12		11	23·11		20	32·91
17	2	53·48		12	3·68		21	13·66	11	6	23·45
	12	44·06		21	54·23	4	7	4·21		16	13·98
	22	34·63	25	7	44·79		16	4·76	12	2	4·51

System I.

G.M.T.			G.M.T.			G.M.T.			G.M.T.		
1901. d	h	m	1901. d	h	m	1901. d	h	m	1901. d	h	m
Mar. 12	11	55·04	Mar. 28	1	54·94	Apr. 12	15	53·83	Apr. 28	5	51·75
	21	45·58		11	45·45	13	1	44·34		15	42·21
13	7	36·12		21	35·96		11	34·80	29	1	32·67
	17	26·65	29	7	26·47		21	25·28		11	23·13
14	3	17·18		17	16·98	14	7	15·76		21	13·59
	13	7·72	30	3	7·48		17	6·24	30	7	4·04
	22	58·25		12	57·99	15	2	56·72		16	54·49
15	8	48·78		22	48·49		12	47·20	May 1	2	44·95
	18	39·31	31	8	38·99		22	37·68		12	35·40
16	4	29·84		18	29·49	16	8	28·15		22	25·85
	14	20·37	Apr. 1	4	19·99		18	18·63	2	8	16·30
17	0	10·90		14	10·49	17	4	9·11		18	6·76
	10	1·43	2	0	0·99		13	59·59	3	3	57·21
	19	51·96		9	51·49		23	50·07		13	47·66
18	5	42·49		19	41·99	18	9	40·54		23	38·11
	15	33·02	3	5	32·49		19	31·02	4	9	28·57
19	1	23·55		15	22·99	19	5	21·49		19	19·02
	11	14·07	4	1	13·49		15	11·96	5	5	9·46
	21	4·60		11	3·99	20	1	2·43		14	59·92
20	6	55·12		20	54·49		10	52·91	6	0	50·36
	16	45·64	5	6	44·99		20	43·39		10	40·81
21	2	36·16		16	35·49	21	6	33·86		20	31·25
	12	26·68	6	2	25·98		16	24·33	7	6	21·69
	22	17·20		12	16·48	22	2	14·80		16	12·13
22	8	7·72		22	6·97		12	5·27	8	2	2·58
	17	58·24	7	7	57·46		21	55·74		11	53·02
23	3	48·76		17	47·95	23	7	46·20		21	43·47
	13	39·28	8	3	38·45		17	36·67	9	7	33·91
	23	29·80		13	28·95	24	3	27·14		17	24·36
24	9	20·32		23	19·44		13	17·60	10	3	14·80
	19	10·84	9	9	9·93		23	8·07		13	5·24
25	5	1·36		19	0·43	25	8	58·53		22	55·68
	14	51·88	10	4	50·92		18	48·99	11	8	46·12
26	0	42·39		14	41·41	26	4	39·45		18	36·56
	10	32·90	11	0	31·90		14	29·91	12	4	27·00
	20	23·41		10	22·39	27	0	20·37		14	17·44
27	6	13·92		20	12·87		10	10·83	13	0	7·88
	16	4·43	12	6	3·35		20	1·29		9	58·32

System I.

G.M.T.			G.M.T.			G.M.T.			G.M.T.		
1901. d	h	m	1901. d	h	m	1901. d	h	m	1901. d	h	m
May 13	19	48·76	May 29	9	44·92	June 13	23	40·57	June 29	13	36·14
14	5	39·19		19	35·34	14	9	30·98		23	26·55
	15	29·62	30	5	25·76		19	21·39	30	9	16·96
15	1	20·05		15	16·17	15	5	11·79		19	7·37
	11	10·48	31	1	6·59		15	2·20	July 1	4	57·78
	21	0·91		10	57·01	16	0	52·61		14	48·20
16	6	51·34		20	47·42		10	43·02	2	0	38·61
	16	41·77	June 1	6	37·84		20	33·43		10	29·02
17	2	32·20		16	28·26	17	6	23·84		20	19·44
	12	22·63	2	2	18·67		16	14·25	3	6	9·85
	22	13·06		12	9·09	18	2	4·65		16	0·27
18	8	3·49		21	59·50		11	55·06	4	1	50·69
	17	53·92	3	7	49·92		21	45·47		11	41·11
19	3	44·35		17	40·33	19	7	35·88		21	31·53
	13	34·78	4	3	30·75		17	26·28	5	7	21·95
	23	25·21		13	21·16	20	3	16·69		17	12·37
20	9	15·64		23	11·57		13	7·10	6	3	2·79
	19	6·07	5	9	1·99		22	57·51		12	53·21
21	4	56·50		18	52·40	21	8	47·91		22	43·64
	14	46·92	6	4	42·81		18	38·32	7	8	34·06
22	0	37·36		14	33·22	22	4	28·73		18	24·49
	10	27·78	7	0	23·63		14	19·14	8	4	14·91
	20	18·20		10	14·04	23	0	9·55		14	5·34
23	6	8·63		20	4·45		9	59·96		23	55·77
	15	59·05	8	5	54·86		19	50·37	9	9	46·19
24	1	49·48		15	45·27	24	5	40·79		19	36·62
	11	39·90	9	1	35·68		15	31·20	10	5	27·05
	21	30·32		11	26·08	25	1	21·61		15	17·48
25	7	20·74		21	16·49		11	12·03	11	1	7·91
	17	11·16	10	7	6·90		21	2·44		10	58·33
26	3	1·58		16	57·31	26	6	52·85		20	48·76
	12	51·99	11	2	47·72		16	43·26	12	6	39·19
	22	42·41		12	38·13	27	2	33·67		16	29·62
27	8	32·83		22	28·54		12	24·08	13	2	20·05
	18	23·25	12	8	18·95		22	14·49		12	10·48
28	4	13·67		18	9·35	28	8	4·90		22	0·91
	14	4·09	13	3	59·76		17	55·32	14	7	51·34
	23	54·50		13	50·17	29	3	45·73		17	41·77

System I.

	G.M.T.				G.M.T.				G.M.T.				G.M.T.		
1901.	d	h	m	1901.	d	h	m	1901.	d	h	m	1901.	d	h	m
July	15	3	32·21	July	30	17	29·47	Aug.	15	7	28·23	Aug.	30	21	28·51
		13	22·65		31	3	19·95			17	18·74		31	7	19·07
		23	13·09			13	10·43		16	3	9·26			17	9·62
	16	9	3·53			23	0·91			12	59·77	Sept.	1	3	0·18
		18	53·97	Aug.	1	8	51·39			22	50·29			12	50·74
	17	4	44·41			18	41·87		17	8	40·81			22	41·29
		14	34·86		2	4	32·35			18	31·32		2	8	31·85
	18	0	25·30			14	22·83		18	4	21·83			18	22·41
		10	15·74		3	0	13·31			14	12·35		3	4	12·97
		20	6·19			10	3·79		19	0	2·86			14	3·53
	19	5	56·64			19	54·28			9	53·38			23	54·10
		15	47·09		4	5	44·76			19	43·90		4	9	44·66
	20	1	37·54			15	35·25		20	5	34·43			19	35·22
		11	27·99		5	1	25·74			15	24·96		5	5	25·79
		21	18·44			11	16·23		21	1	15·50			15	16·35
	21	7	8·89			21	6·72			11	6·04		6	1	6·92
		16	59·34		6	6	57·20			20	56·57			10	57·48
	22	2	49·78			16	47·69		22	6	47·10			20	48·05
		12	40·23		7	2	38·18			16	37·64		7	6	38·62
		22	30·68			12	28·67		23	2	28·18			16	29·19
	23	8	21·13			22	19·16			12	18·72		8	2	19·76
		18	11·60		8	8	9·65			22	9·26			12	10·33
	24	4	2·05			18	0·14		24	7	59·80			22	0·90
		13	52·51		9	3	50·63			17	50·34		9	7	51·47
		23	42·97			13	41·12		25	3	40·88			17	42·03
	25	9	33·43			23	31·63			13	31·42		10	3	32·61
		19	23·89		10	9	22·13			23	21·96			13	23·19
	26	5	14·35			19	12·63		26	9	12·50			23	13·77
		15	4·81		11	5	3·13			19	3·04		11	9	4·35
	27	0	55·28			14	53·64		27	4	53·58			18	54·93
		10	45·74		12	0	44·14			14	44·12		12	4	45·51
		20	36·20			10	34·64		28	0	34·67			14	36·09
	28	6	26·67			20	25·15			10	25·21		13	0	26·68
		16	17·14		13	6	15·66			20	15·75			10	17·26
	29	2	7·60			16	6·18		29	6	6·30			20	7·85
		11	58·06		14	1	56·69			15	56·85		14	5	58·44
		21	48·53			11	47·20		30	1	47·40			15	49·03
	30	7	39·00			21	37·72			11	37·95		15	1	39·62

System I.

1901.	G.M.T. d	h	m	1901.	G.M.T. d	h	m	1901.	G.M.T. d	h	m	1901.	G.M.T. d	h	m
Sept.	15	11	30·20	Oct.	1	1	33·07	Oct.	16	15	36·89	Nov.	1	5	41·42
		21	20·78			11	23·69		17	1	27·53			15	32·07
	16	7	11·37			21	14·31			11	18·16		2	1	22·72
		17	1·96		2	7	4·93			21	8·80			11	13·38
	17	2	52·55			16	55·55		18	6	59·44			21	4·03
		12	43·14		3	2	46·17			16	50·08		3	6	54·69
		22	33·73			12	36·79		19	2	40·72			16	45·35
	18	8	24·32			22	27·41			12	31·36		4	2	36·01
		18	14·91		4	8	18·03			22	22·00			12	26·66
	19	4	5·50			18	8·65		20	8	12·64			22	17·32
		13	56·09		5	3	59·27			18	3·28		5	8	7·98
		23	46·69			13	49·90		21	3	53·92			17	58·63
	20	9	37·28			23	40·52			13	44·55		6	3	49·28
		19	27·89		6	9	31·14			23	35·20			13	39·94
	21	5	18·49			19	21·76		22	9	25·84			23	30·60
		15	9·08		7	5	12·38			19	16·49		7	9	21·25
	22	0	59·68			15	3·01		23	5	7·13			19	11·91
		10	50·28		8	0	53·63			14	57·78		8	5	2·57
		20	40·88			10	44·25		24	0	48·43			14	53·23
	23	6	31·49			20	34·88			10	39·08		9	0	43·89
		16	22·09		9	6	25·50			20	29·73			10	34·55
	24	2	12·70			16	16·13		25	6	20·37			20	25·21
		12	3·30		10	2	6·76			16	11·02		10	6	15·87
		21	53·91			11	57·39		26	2	1·67			16	6·53
	25	7	44·51			21	48·01			11	52·32		11	1	57·19
		17	35·12		11	7	38·65			21	42·96			11	47·85
	26	3	25·73			17	29·28		27	7	33·61			21	38·51
		13	16·34		12	3	19·90			17	24·26		12	7	29·17
		23	6·94			13	10·53		28	3	14·91			17	19·83
	27	8	57·55			23	1·16			13	5·56		13	3	10·49
		18	48·16		13	8	51·79			22	56·21			13	1·15
	28	4	38·77			18	42·43		29	8	46·86			22	51·81
		14	29·38		14	4	33·07			18	37·51		14	8	42·47
	29	0	19·99			14	23·71		30	4	28·16			18	33·13
		10	10·59		15	0	14·35			14	18·81		15	4	23·79
		20	1·21			10	4·98		31	0	9·46			14	14·45
	30	5	51·83			19	55·61			10	0·11		16	0	5·11
		15	42·45		16	5	46·25			19	50·77			9	55·77

System I.

1901.	d	G.M.T. h	m	1901.	d	G.M.T. h	m	1901.	d	G.M.T. h	m	1901.	d	G.M.T. h	m
Nov.	16	19	46·43	Nov.	23	19	7·72	Nov.	30	8	38·41	Dec.	6	22	9·07
	17	5	37·10		24	4	58·39			18	29·07		7	7	59·74
		15	27·76			14	49·05	Dec.	1	4	19·74			17	50·41
	18	1	18·43		25	0	39·72			14	10·41		8	3	41·07
		11	9·09			10	30·39		2	0	1·08			13	31·74
		20	59·75			20	21·06			9	51·74			23	22·41
	19	6	50·41		26	6	11·74			19	42·41		9	9	13·08
		16	41·08			16	2·41		3	5	33·07			19	3·74
	20	2	31·75		27	1	53·07			15	23·74		10	4	54·41
		12	22·41			11	43·74		4	1	14·40			14	45·08
		22	13·07			21	34·41			11	5·07		11	0	35·74
	21	8	3·73		28	7	25·08			20	55·73			10	26·41
		17	54·40			17	15·75		5	6	46·40			20	17·09
	22	3	45·06		29	3	6·41			16	37·07		12	6	7·75
		13	35·73			12	57·08		6	2	27·74			15	58·42
		23	26·39			22	47·74			12	18·40		13	1	49·09
	23	9	17·06												

System II.

1901.	d	G.M.T. h	m	1901.	d	G.M.T. h	m	1901.	d	G.M.T. h	m	1901.	d	G.M.T. h	m
Jan.	17	9	3·97	Jan.	24	19	48·18	Feb.	1	6	32·21	Feb.	18	17	16·06
		18	59·77		25	5	43·96			16	27·99		9	3	11·83
	18	4	55·57			15	39·74		2	2	23·76			13	7·59
		14	51·36		26	1	35·52			12	19·53			23	3·35
	19	0	47·15			11	31·30			22	15·30		10	8	59·11
		10	42·95			21	27·08		3	8	11·07			18	54·87
		20	38·74		27	7	22·86			18	6·84		11	4	50·63
	20	6	34·53			17	18·64		4	4	2·60			14	46·39
		16	30·32		28	3	14·42			13	58·37		12	0	42·15
	21	2	26·11			13	10·20			23	54·13			10	37·91
		12	21·90			23	5·98		5	9	49·90			20	33·67
		22	17·68		29	9	1·76			19	45·67		13	6	29·43
	22	8	13·46			18	57·54		6	5	41·44			16	25·19
		18	9·25		30	4	53·32			15	37·21		14	2	20·94
	23	4	5·04			14	49·10		7	1	32·98			12	16·69
		14	0·83		31	0	44·87			11	28·75			22	12·44
		23	56·61			10	40·65			21	24·52		15	8	8·19
	24	9	52·40			20	36·43		8	7	20·29			18	3·94

System II.

	G.M.T.				G.M.T.				G.M.T.				G.M.T.		
1901.	d	h	m	1901.	d	h	m	1901.	d	h	m	1901.	d	h	m
Feb.	16	3	59·69	Mar.	3	21	17·82	Mar.	19	14	35·01	Apr.	4	7	51·17
		13	55·45		4	7	13·54		20	0	30·71			17	46·84
		23	51·20			17	9·27			10	26·41		5	3	42·52
	17	9	46·96		5	3	4·99			20	22·11			13	38·19
		19	42·71			13	0·72		21	6	17·81			23	33·87
	18	5	38·47			22	56·44			16	13·51		6	9	29·54
		15	34·22		6	8	52·16		22	2	9·21			19	25·22
	19	1	29·97			18	47·89			12	4·91		7	5	20·89
		11	25·71		7	4	43·61			22	0·61			15	16·57
		21	21·46			14	39·33		23	7	56·31		8	1	12·24
	20	7	17·20		8	0	35·05			17	52·00			11	7·92
		17	12·95			10	30·77		24	3	47·69			21	3·59
	21	3	8·68			20	26·49			13	43·37		9	6	59·26
		13	4·42		9	6	22·21			23	39·06			16	54·93
		23	0·16			16	17·93		25	9	34·75		10	2	50·60
	22	8	55·91		10	2	13·65			19	30·44			12	46·28
		18	51·65			12	9·36		26	5	26·13			22	41·95
	23	4	47·40			22	5·08			15	21·82		11	8	37·62
		14	43·14		11	8	0·79		27	1	17·51			18	33·29
	24	0	38·88			17	56·50			11	13·20		12	4	28·95
		10	34·62		12	3	52·21			21	8·89			14	24·60
		20	30·35			13	47·93		28	7	4·58		13	0	20·25
	25	6	26·09			23	43·64			17	0·26			10	15·90
		16	21·83		13	9	39·35		29	2	55·95			20	11·56
	26	2	17·57			19	35·06			12	51·63		14	6	7·21
		12	13·31		14	5	30·77			22	47·32			16	2·87
		22	9·04			15	26·49		30	8	43·00		15	1	58·52
	27	8	4·78		15	1	22·20			18	38·69			11	54·18
		18	0·52			11	17·91		31	4	34·37			21	49·83
	28	3	56·25			21	13·62			14	30·06		16	7	45·48
		13	51·98		16	7	9·33	Apr.	1	0	25·74			17	41·13
		23	47·72			17	5·04			10	21·43		17	3	36·79
Mar.	1	9	43·45		17	3	0·75			20	17·11			13	32·45
		19	39·18			12	56·46		2	6	12·79			23	28·10
	2	5	34·91			22	52·17			16	8·47		18	9	23·76
		15	30·64		18	8	47·88		3	2	4·14			19	19·41
	3	1	26·37			18	43·59			11	59·82		19	5	15·07
		11	22·09		19	4	39·30			21	55·49			15	10·72

System II.

1901.	G.M.T. d	h	m	1901.	G.M.T. d	h	m	1901.	G.M.T. d	h	m	1901.	G.M.T. d	h	m
Apr.	20	1	6·38	May	5	18	20·55	May	21	11	33·83	June	6	4	46·39
		11	2·03		6	4	16·17			21	29·43			14	41·98
		20	57·69			14	11·79		22	7	25·04		7	0	37·56
	21	6	53·34		7	0	7·41			17	20·64			10	33·15
		16	48·99			10	3·03		23	3	16·24			20	28·73
	22	2	44·64			19	58·65			13	11·83		8	6	24·32
		12	40·29		8	5	54·27			23	7·43			16	19·90
		22	35·92			15	49·89		24	9	3·03		9	2	15·49
	23	8	31·55		9	1	45·51			18	58·62			12	11·07
		18	27·19			11	41·13		25	4	54·22			22	6·66
	24	4	22·82			21	36·74			14	49·81		10	8	2·24
		14	18·46		10	7	32·36		26	0	45·41			17	57·82
	25	0	14·09			17	27·98			10	41·00		11	3	53·41
		10	9·73		11	3	23·60			20	36·60			13	49·00
		20	5·36			13	19·22		27	6	32·20			23	44·58
	26	6	0·99			23	14·84			16	27·80		12	9	40·17
		15	56·62		12	9	10·45		28	2	23·40			19	35·75
	27	1	52·26			19	6·06			12	18·99		13	5	31·34
		11	47·90		13	5	1·67			22	14·59			15	26·92
		21	43·54			14	57·28		29	8	10·18		14	1	22·51
	28	7	39·18		14	0	52·89			18	5·78			11	18·09
		17	34·82			10	48·49		30	4	1·37			21	13·68
	29	3	30·46			20	44·10			13	56·97		15	7	9·26
		13	26·10		15	6	39·71			23	52·56			17	4·85
		23	21·74			16	35·32		31	9	48·16		16	3	0·44
	30	9	17·39		16	2	30·93			19	43·75			12	56·03
		19	13·03			12	26·54	June	1	5	39·35			22	51·61
May	1	5	8·67			22	22·15			15	34·95		17	8	47·20
		15	4·31		17	8	17·76		2	1	30·54			18	42·78
	2	0	59·95			18	13·37			11	26·12		18	4	38·37
		10	55·58		18	4	8·98			21	21·71			14	33·95
		20	51·20			14	4·58		3	7	17·29		19	0	29·53
	3	6	46·82		19	0	0·19			17	12·88			10	25·11
		16	42·44			9	55·80		4	3	8·46			20	20·69
	4	2	38·06			19	51·40			13	4·05		20	6	16·27
		12	33·69		20	5	47·01			22	59·63			16	11·85
		22	29·31			15	42·62		5	8	55·22		21	2	7·45
	5	8	24·93		21	1	38·22			18	50·80			12	3·03

System II.

1901.	G.M.T. d	h	m	1901.	G.M.T. d	h	m	1901.	G.M.T. d	h	m	1901.	G.M.T. d	h	m
June	21	21	58·61	July	7	15	10·99	July	23	8	24·33	Aug.	8	1	39·08
	22	7	54·19		8	1	6·58			18	19·97			11	34·75
		17	49·77			11	2·18		24	4	15·60			21	30·42
	23	3	45·35			20	57·77			14	11·24		9	7	26·08
		13	40·94		9	6	53·37		25	0	6·88			17	21·75
		23	36·52			16	48·96			10	2·51		10	3	17·44
	24	9	32·11		10	2	44·56			19	58·15			13	13·11
		19	27·69			12	40·15		26	5	53·79			23	8·79
	25	5	23·28			22	35·74			15	49·43		11	9	4·47
		15	18·86		11	8	31·35		27	1	45·07			19	0·15
	26	1	14·45			18	26·96			11	40·70		12	4	55·83
		11	10·04		12	4	22·58			21	36·34			14	51·51
		21	5·62			14	18·19		28	7	31·98		13	0	47·19
	27	7	1·21		13	0	13·81			17	27·61			10	42·88
		16	56·79			10	9·42		29	3	23·25			20	38·57
	28	2	52·38			20	5·04			13	18·89		14	6	34·26
		12	47·96		14	6	0·65			23	14·52			16	29·95
		22	43·55			15	56·27		30	9	10·16		15	2	25·65
	29	8	39·13		15	1	51·88			19	5·79			12	21·36
		18	34·72			11	47·50		31	5	1·43			22	17·07
	30	4	30·30			21	43·12			14	57·09		16	8	12·78
		14	25·89		16	7	38·74	Aug.	1	0	52·76			18	8·48
July	1	0	21·47			17	34·36			10	48·42		17	4	4·18
		10	17·06		17	3	29·98			20	44·09			13	59·89
		20	12·66			13	25·60		2	6	39·75			23	55·60
	2	6	8·25			23	21·21			16	35·42		18	9	51·30
		16	3·85		18	9	16·83		3	2	31·09			19	47·00
	3	1	59·44			19	12·45			12	26·75		19	5	42·69
		11	55·04		19	5	8·07			22	22·42			15	38·39
		21	50·63			15	3·68		4	8	18·09		20	1	34·08
	4	7	46·23		20	0	59·30			18	13·75			11	29·78
		17	41·82			10	54·91		5	4	9·42			21	25·47
	5	3	37·42			20	50·53			14	5·09		21	7	21·17
		13	33·01		21	6	46·15		6	0	0·76			17	16·86
		23	28·60			16	41·78			9	56·42		22	3	12·57
	6	9	24·20		22	2	37·42			19	52·08			13	8·28
		19	19·80			12	33·06		7	5	47·75			23	4·00
	7	5	15·39			22	28·69			15	43·42		23	8	59·70

System II.

	G.M.T.				G.M.T.				G.M.T.				G.M.T.		
1901.	d	h	m	1901.	d	h	m	1901.	d	h	m	1901.	d	h	m
Aug.	23	18	55·41	Sept.	8	12	13·20	Sept.	24	5	32·36	Oct.	9	22	52·58
	24	4	51·11			22	8·95			15	28·14		10	8	48·39
		14	46·82		9	8	4·71		25	1	23·92			18	44·20
	25	0	42·53			18	0·49			11	19·70		11	4	40·01
		10	38·24		10	3	56·24			21	15·48			14	35·83
		20	33·95			13	52·00		26	7	11·27		12	0	31·64
	26	6	29·67			23	47·75			17	7·05			10	27·45
		16	25·38		11	9	43·51		27	3	2·84			20	23·26
	27	2	21·10			19	39·26			12	58·63		13	6	19·08
		12	16·82		12	5	35·03			22	54·42			16	14·89
		22	12·55			15	30·78		28	8	50·21		14	2	10·70
	28	8	8·27		13	1	26·54			18	46·00			12	6·51
		18	4·00			11	22·30		29	4	41·80			22	2·33
	29	3	59·72			21	18·06			14	37·59		15	7	58·14
		13	55·45		14	7	13·82		30	0	33·38			17	53·95
		23	51·17			17	9·58			10	29·17		16	3	49·76
	30	9	46·90		15	3	5·35			20	24·96			13	45·58
		19	42·63			13	1·11	Oct.	1	6	20·75			23	41·40
	31	5	38·37			22	56·88			16	16·55		17	9	37·21
		15	34·10		16	8	52·66		2	2	12·35			19	33·03
Sept.	1	1	29·84			18	48·43			12	8·15		18	5	28·85
		11	25·57		17	4	44·20			22	3·95			15	24·67
		21	21·31			14	39·97		3	7	59·75		19	1	20·49
	2	7	17·05		18	0	35·75			17	55·55			11	16·31
		17	12·79			10	31·52		4	3	51·35			21	12·13
	3	3	8·53			20	27·29			13	47·15		20	7	7·94
		13	4·27		19	6	23·06			23	42·95			17	3·77
		23	0·01			16	18·83		5	9	38·75		21	2	59·59
	4	8	55·75		20	2	14·60			19	34·55			12	55·41
		18	51·49			12	10·37		6	5	30·35			22	51·23
	5	4	47·25			22	6·14			15	26·15		22	8	47·05
		14	42·97		21	8	1·92		7	1	21·95			18	42·88
	6	0	38·71			17	57·69			11	17·75		23	4	38·70
		10	34·46		22	3	53·47			21	13·56			14	34·53
		20	30·20			13	49·25		8	7	9·36		24	0	30·36
	7	6	25·95			23	45·02			17	5·16			10	26·19
		16	21·69		23	9	40·80		9	3	0·96			20	22·02
	8	2	17·45			19	36·58			12	56·77		25	6	17·84

System II.

	G.M.T.				G.M.T.				G.M.T.				G.M.T.		
1901.	d	h	m	1901.	d	h	m	1901.	d	h	m	1901.	d	h	m
Oct.	25	16	13·67	Nov.	7	2	8·63	Nov.	19	12	3·83	Dec.	1	12	3·36
	26	2	9·49			12	4·47			21	59·68			21	59·21
		12	5·32			22	0·30		20	7	55·52		2	7	55·05
		22	1·15		8	7	56·13			17	51·36			17	50·90
	27	7	56·98			17	51·97		21	3	47·21		3	3	46·75
		17	52·80		9	3	47·81			13	43·05			13	42·60
	28	3	48·63			13	43·65			23	38·89			23	38·45
		13	44·46			23	39·48		22	9	34·74		4	9	34·29
		23	40·29		10	9	35·32			19	30·58			19	30·14
	29	9	36·12			19	31·16		23	5	26·42		5	5	25·99
		19	31·95		11	5	27·00			15	22·26			15	21·84
	30	5	27·78			15	22·84		24	1	18·10		6	1	17·69
		15	23·61		12	1	18·68			11	13·95			11	13·54
	31	1	19·43			11	14·53			21	9·79			21	9·38
		11	15·26			21	10·37		25	7	5·63		7	7	5·22
		21	11·09		13	7	6·21			17	1·48			17	1·09
Nov.	1	7	6·93			17	2·05		26	2	57·33		8	2	56·93
		17	2·75		14	2	57·89			12	53·17			12	52·77
	2	2	58·58			12	53·73			22	49·02			22	48·61
		12	54·42			22	49·57		27	8	44·87		9	8	44·46
		22	50·25		15	8	45·42			18	40·71			18	40·31
	3	8	46·09			18	41·26		28	4	36·56		10	4	36·16
		18	41·93		16	4	37·10			14	32·41			14	32·00
	4	4	37·77			14	32·94		29	0	28·26		11	0	27·85
		14	33·60		17	0	28·78			10	24·11			10	23·70
	5	0	29·44			10	24·63			20	19·96			20	19·55
		10	25·28			20	20·47		30	6	15·81		12	6	15·39
		20	21·11		18	6	16·31			16	11·66			16	11·24
	6	6	16·95			16	12·15	Dec.	1	2	7·51		13	2	7·08
		16	12·79		19	2	7·99								

The quantities in the ephemeris are to be interpolated directly for the times for which they are required, the equation of light having been already applied.

The position of *Jupiter's* North Pole is assumed to be R.A. $17^h\ 51^m\ 59^s{\cdot}22$, N.P.D. 25° 26′ 24″·6 at the beginning of 1901, and R.A. $17^h\ 51^m\ 59^s{\cdot}49$, N.P.D. 25° 26′ 25″·3 at the beginning of 1902.

P denotes the position-angle of the northern extremity of *Jupiter's* axis, reckoned eastward from the northernmost point of the disc.

$L-O+180°$, $\Lambda-O+180°$ are the jovicentric right ascensions of the Earth and Sun respectively, reckoned in the plane of the planet's equator from O, the point of the vernal equinox of *Jupiter's* northern hemisphere; B, *B* are the jovicentric declinations of the Earth and Sun above the planet's equator.

I have made a change in the adopted values of the equatorial and polar diameters. Professor T. J. J. See recently made a new series of measures with coloured screens which are published in *Ast. Nach.* 3670. Giving equal weights to his results, those of Professor Barnard, and those obtained with the 28-inch equatorial at Greenwich, the resulting diameters at distance 5·20 are: Equatorial, 38″·373; Polar, 35″·991. I have not, however, adopted these as they stand, but have sought for a quantity which, when added to the equatorial diameter and subtracted from the polar diameter, would give to the oblateness $\frac{a-b}{a}$ the exact value $\frac{1}{15\cdot53}$ which was deduced by Professors Cohn and W. S. Adams from the observed motion of the perijove of the fifth satellite, as this method of determining the oblateness is probably more reliable than those depending on direct measures of the disc. The finally adopted values at distance 5·20 are: Equatorial, 38″·419; Polar, 35″·945. The previously adopted values (those of Professor Barnard) are diminished at distance 5·20 by: Equatorial, 0″·103; Polar, 0″·167.

The assumed time for light to traverse the unit distance is $498^s\cdot92$, this being the same value as that used by Mr. Marth.

d denotes the jovicentric angle between the Earth and Sun.

Q denotes the position-angle of the point of greatest phase, and is reckoned eastward from the northernmost point of the disc. It also gives the position-angle of the shadows of the satellites measured from the satellites themselves. I have substituted Q for the angle *w* tabulated in recent years as probably more useful to most observers.

B′ is obtained from B by the formula $\tan B'=\sec \epsilon_0 \tan B$, where $\sec \epsilon_0=\frac{a}{b}=\frac{15\cdot53}{14\cdot53}$. Since B, B′ can never exceed some 3°, we may take the tangents as proportional to the angles. Hence it suffices in practice to find B′ by the formula $B'=\frac{15\cdot53}{14\cdot53}B$. This is the same formula as that by which B′ has been found in recent years, but the multiplier has been altered to correspond with the new value of the oblateness. I have discovered, however, that in my previous ephemerides I have inadvertently followed Mr. Marth in an error in stating that B′ computed by the above formula is the jovigraphical latitude of the centre of the disc. It is in reality the eccentric angle of the centre of the disc. If we call B″ the true jovigraphical latitude of the centre of the disc, then we could find B″ by the formulæ:

$$\tan B''=\sec^2 \epsilon_0 \tan B \quad \text{or} \quad \tan B''=\sec \epsilon_0 \tan B'.$$

Mr. Marth's formulæ on p. 533 of vol. lvi. of the *Monthly Notices* are also wrong. He calls β the jovicentric latitude of a spot and β' the jovigraphical latitude; but the formulæ that he gives imply that the quantity β' is really the eccentric angle of the spot. If we use his formulæ to find β', then we can deduce the true jovigraphical latitude β'' of the spot by the formula $\tan \beta'' = \sec \epsilon_0 \tan \beta'$.

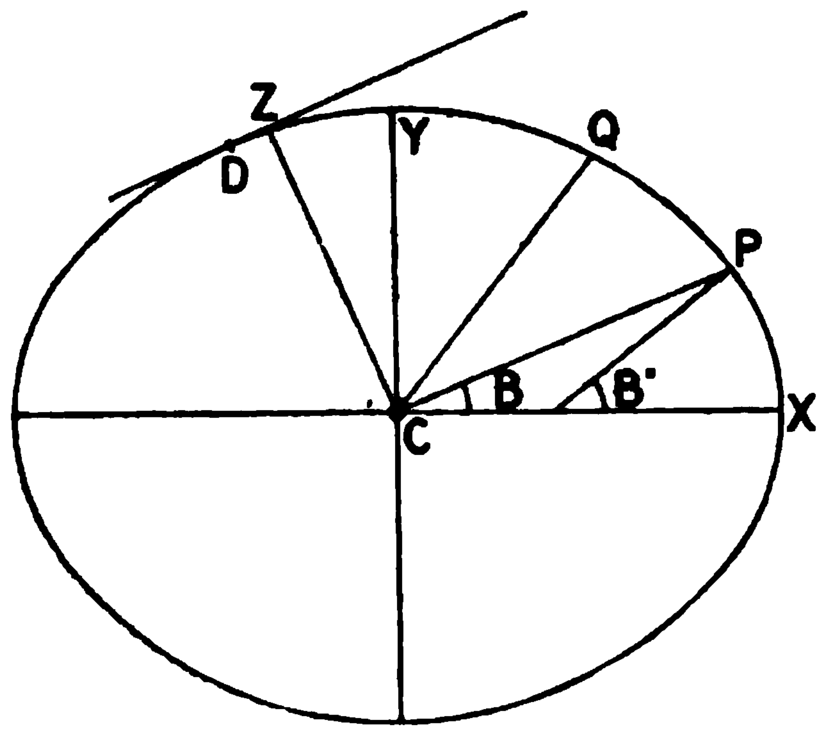


Diagram illustrating the determination of the latitude of Jovian markings and of the centre of the disc.

In order to avoid all possibility of mistake I give the proofs of these formulæ. The ellipse in the figure represents a section of *Jupiter* along that meridian which is central as seen from the Earth. CX, CY are the equatorial and polar radii in this plane, and are taken as the axes of Cartesian coordinates. Then $CX = a$, $CY = b$.

CP is the line joining the centres of the Earth and *Jupiter*; thus P is the apparent centre of the disc. The oblateness of *Jupiter* and the latitude of the centre of the disc are both exaggerated for the sake of clearness.

Then by definition the angle $PCX = B$.

And if B' denote the eccentric angle of the point P, then the coordinates of P are $a \cos B'$, $b \sin B'$.

$$\text{Hence } \tan B = \tan PCX = \frac{b \sin B'}{a \cos B'}.$$

$$\text{That is, } \tan B' = \frac{a}{b} \tan B = \sec \epsilon_0 \tan B.$$

Again, the jovigraphical latitude (B'') of P is the angle which the normal at P makes with CX.

But since the equation to the tangent at P is

$$\frac{x \cos B'}{a} + \frac{y \sin B'}{b} = 1$$

we see that $\tan B'' = \frac{a}{b} \tan B' = \sec \epsilon_0 \tan B'$

$$= \sec^2 \epsilon_0 \tan B.$$

Again, let CD be conjugate to CP, and let CZ be perpendicular to the tangent at D. Then CZ is the apparent polar semi-diameter.

Let Q be a spot on the central meridian whose measured distance from the centre of the disc is η. (Mr. Marth calls this y, but I prefer to use η, as I have used y for ordinates to the principal axis.)

Let β, β', β'' denote respectively the jovicentric latitude, eccentric angle, and jovigraphical latitude of the point Q.

Then $$\eta = CQ \sin QCP = CQ \sin (\beta - B).$$

Again the coordinates of Q are $CQ \cos \beta$, $CQ \sin \beta$.
But they are also $a \cos \beta'$, $b \sin \beta'$.
Hence $CQ \cos \beta = a \cos \beta'$, $CQ \sin \beta = b \sin \beta'$.
Hence $\eta = b \sin \beta' \cos B - a \cos \beta' \sin B$.
But we have in like manner $CP \cos B = a \cos B'$, $CP \sin B = b \sin B'$.

Hence $\eta = \frac{a\,b}{CP} \sin (\beta' - B')$.

But by a well-known property of the ellipse $CZ = \frac{ab}{CP}$.

Hence $\frac{\eta}{CZ} = \sin (\beta' - B')$.

And in an exactly similar manner to the proof for B'' we can show that $\tan \beta'' = \sec \epsilon_0 \tan \beta'$.

I assume Q to be on the central meridian, as in practice all observations for latitude are or should be made in that position.

In the above investigation a, b, η, CZ are supposed to stand for linear dimensions; but since in the final formulæ we are only concerned with the ratios $\frac{a}{b}$ or $\frac{\eta}{CZ}$, we may express a, b, η, CZ in these formulæ in seconds of arc without affecting the ratios.

It would be well that any latitude investigations that have been made with the erroneous formula should be revised with the correct one.

The longitudes of *Jupiter's* central meridian are computed with unaltered values of the rates of rotation and of the zero-meridians in the two adopted systems. The addition of the "Corr. for Phase" gives the longitudes of the meridians which bisect the illuminated disc.

The periods of sidereal rotation corresponding to the two adopted systems are $9^h\ 50^m\ 30^s{\cdot}004$, $9^h\ 55^m\ 40^s{\cdot}632$.

According to J. Comas Sola, the longitude of the centre of the bay containing the great red spot was $33°$ in March 1900, and $39°$ at the end of June 1900 (*Astr. Nach.* 3671). According to

M. Antoniadi, it was 45° on 1900 October 19. Hence it will probably be about 50° at the commencement of the present ephemeris, and will increase to 60° or more at the end of it.

I.e. in January 1901 the red spot will follow the zero-meridian of System II. by about $1^h\ 23^m$, and this may increase to about $1^h\ 40^m$ in December 1901.

According to J. Comas Sola, the average rotation period of a large number of equatorial spots has been $9^h\ 50^m\ 23^s$ in 1899 and 1900, that is 7^s shorter than the adopted value in System I.

Rev. T. E. R. Phillips has deduced $9^h\ 50^m\ 24^s$ for the period of the south equatorial belt from observations in 1898, 1899, 1900. He gets $9^h\ 55^m\ 41^s{\cdot}66$ as the average rotation period of the great red spot during the same three years.

There will be a transit of the Earth across the Sun as seen from *Jupiter* on 1901 June 30.

As seen from *Jupiter's* centre, the Earth's centre will appear to enter on the Sun June $29^d\ 23^h\ 49^m$ G.M.T., and will appear to leave the Sun June $30^d\ 11^h\ 20^m$ G.M.T. The least distance of centres ($25''{\cdot}5$) will occur at $5^h\ 34^m$ G.M.T. The semidiameters of the Sun and Earth as seen from *Jupiter* will be $184''{\cdot}2$ and $2''{\cdot}1$.

The only visible effect of the transit will be the fact that Satellite I. during its transit on June 30 will be almost centrally superposed on its own shadow. Owing to the penumbral fringe the shadow appears larger than the satellite, so that it may be seen as a dusky ring round the latter. This will be a most interesting phenomenon for scrutiny with large instruments, and will be observable in Europe and Africa. Ingress occurs at $10^h\ 4^m$ and egress at $12^h\ 21^m$. Prof. Barnard observed a partial occultation of the shadow by the satellite 1893 Nov. 19, though there was no transit in that year (*Monthly Notices*, liv. 3, p. 135).

A few words as to the laws of recurrence of transits of the Earth seen from *Jupiter* may be of interest. I find that a transit occurs when the planet passes through its node within 114 days of opposition. Thus considering the passages of the descending node :—

In 1889 the node was passed 72 days after opposition.
Hence a transit occurred.
In 1901 the node is passed 15 days after opposition. Transit.
In 1913 node passed 41 days before opposition. Transit.
In 1925 node passed 96 days before opposition. Transit.
In 1937 node passed 151 days before opposition. No transit.
In 1949 node passed 207 days before opposition. No transit.
i.e. 192 days after opposition of 1948. No transit.
In 1960 node passed 137 days after opposition. No transit.

Continuing, we find that 1972 corresponds, within a few days, with 1889, and so on. We thus get 4 nodal passages with transits

followed by 3 nodal passages without transits, after which the cycle recurs.

At the other node we find that transits occur in 1894, 1906, 1919, 1931, then occur 3 nodal passages unaccompanied by transits, followed after the 83-year cycle by 4 more passages with transits, and so on. Thus between 1889 and 1931 there are 8 transits, while a transitless interval of 41½ years precedes and follows.*

Another season of eclipses and transits of Satellite IV. is commencing. According to the *Nautical Almanac* the first occultation of the satellite occurs on March 12, the first transit on March 20, the second and third occultations on March 28, April 14, the second and third transits on April 6, 22, the first eclipse on April 30, the first transit of shadow on May 9.

The satellite should be carefully examined on March 28 about $7^h\ 32^m$, and on April 14 about $1^h\ 35^m$, to see whether it enters the shadow of the planet either wholly or partially. The second tabular eclipse on May 17 is visible in Europe, and should be carefully observed. The duration of these early eclipses is very uncertain, and the predicted times of beginning and ending may be greatly in error. It seems unadvisable to give the prediction of these early eclipses to seconds of time, as is done in the *Nautical Almanac.* An error of 30 minutes in the time of disappearance and reappearance is not at all improbable.

Another interesting phenomenon that will take place next year is the conjunction of *Jupiter* and *Saturn.* It is true that the conjunction is not very close, the least distance of centres being 26′ 28″; but with the exception of the triple conjunction in 1683 it is the closest since the invention of the telescope, and affords an opportunity—the only one till 1961—of studying the two giant planets in the same low-power field.

The following little table gives the distance between the planets in longitude and latitude at noon on the days named :—

1901.		Difference of Longitude.		Difference of Latitude. Jupiter South.	Distance of Centres.	Elongation from Sun.
		′		′ ″	′	°
Nov.	21	45	♃ West	26 33	52	45
	23	33	,,	26 31	42	43
	25	21	,,	26 30	33	41
	27	7·6	,,	26 29	27	39
	29	5·1	♃ East	26 28	27	37
Dec.	1	18	,,	26 27	32	35
	3	31	,,	26 26	41	34
	5	44	,,	26 25	51	32

* Many of these relations were given by Mr. Marth in a paper in *Monthly Notices*, xlvi. 3, p. 161.

The planets will be 3° 18′ apart on 1901 May 5. Their distance will then increase to 6° 54′ on August 16, after which they will approach till the conjunction.

I have given fuller details of past and future conjunctions of the planets in the *Journal* of the British Astronomical Association (vii. 3, p. 128).

A list of the times of elongation of the fifth satellite is given in the *Connaissance des Temps* for 1901. The East and West elongations given there for 1899 require to be interchanged. This has been corrected in 1900 and 1901.

It may be mentioned here that the *Connaissance des Temps* for 1899 and following years gives ephemerides for the satellites of *Mars*, *Saturn*, *Uranus* and *Neptune* in the same form as those formerly contributed to the *Monthly Notices* by Mr. Marth.

Benvenue, 55 *Ulundi Road, Blackheath, S.E.:*
1900 *December* 10.

MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

VOL. LXI. JANUARY 11, 1901. No. 3

E. B. KNOBEL, Esq., President, in the Chair.

Charles Anthony, jun., M.Inst.C.E., Casilla 1045, Buenos Aires, Argentine Republic;
Henry Osmund Barnard, Superintendent, Trigonometrical Surveys, Ceylon;
Archibald Young Gipps Campbell, I.C.S., Nandiyal Railway Station P.O., Kurnool District, South India;
Charles Rundle Davidson, Royal Observatory, and 41 Park Street, Greenwich, S.E.;
Frank C. Dumat, Johannesburg, Transvaal, South Africa;
Ambrose T. Flagg, M.A., Chapel House, Westoe, South Shields;
Walter Heath, M.A., Redcott, Cobham, Surrey;
John Charles William Herschel, B.A. Oxon, St. John's College, Cambridge, and Lawn Upton, Littlemore, near Oxford;
James Netherclift Jutsum, Cardiff Nautical Academy, 47 Fitzhamon Embankment, Cardiff, South Wales;
Captain Joseph W. Martyr, 1 The Glen, South Road, Forest Hill, S.E.;
Alfred Ernest Moore, B.A., B.Sc. (Lond.), St. John's College, Battersea, S.W.;
Thomas Marginson Nightingale, B.Sc. (Vict.), 375 Bridgman Street, Bolton, Lancashire; and
Richard Welford, M.A., J.P., Thornfield, Gosforth, near Newcastle-on-Tyne,

were balloted for and duly elected Fellows of the Society.

The following candidates were proposed for election as Fellows of the Society, the names of the proposers from personal knowledge being appended :—

Robert William Chapman, M.A., B.C.E., Lecturer on Engineering and Physical Science in the University, Adelaide, South Australia (proposed by Sir C. Todd); and
Charles J. Isaacs, Head of the Upper Nautical School, Greenwich, S.E. (proposed by Thomas Lewis).

Fifty-three presents were announced as having been received since the last meeting, including, amongst others :—

Greenwich Second Ten-year Catalogue of 6892 stars for the epoch 1890·0, presented by the Observatory; Series of twenty-six Charts of Borneo, Sumatra, &c., for the use of observers of the total solar eclipse of May 1901, presented by Professor Bakhuyzen.

On mechanically compensating the rotation of the field of a Siderostat. By H. H. Turner, D.Sc., F.R.S., Savilian Professor.

1. In the *Astrophysical Journal* for March 1900, M. Cornu has given an elegant investigation of the rotation of the siderostat field. To the geometry of his paper little or nothing can be added; but he has left untouched the question of any mechanical compensation of the variable rotation described, of which I propose to treat in the present note. Some simple link-work arrangements are suggested which it is hoped may be found to solve the problem of compensation practically.

2. Let P (in fig. 1) denote the pole of the heavens; T the direction in which the telescope is directed, looking from mirror through the OG to the eye end; and draw the meridian PT, which is not necessarily the meridian of the zenith but that of the telescope.

Consider what happens as a star S passes from upper culmination (on the *telescope* meridian) at S_1 to lower culmination at S_2. If the siderostat reflects its image in the constant direction T, then at upper culmination the normal to the mirror is directed towards N_1 where N_1 bisects the arc TS_1. The pole P will thus be reflected to R_1 *below* T; and since $PN_1=N_1R_1$, we have $TR_1=PS_1$. Similarly at lower culmination the pole is reflected to R_2. And it is easily seen geometrically, as is shown in

M. Cornu's paper, that the image of P describes a circle about T, with radius TR equal to the radius PS, of the circle described by the star about P. The essential difference between the description of the two equal circles is that S moves round P uniformly, but R does *not* move round T uniformly.

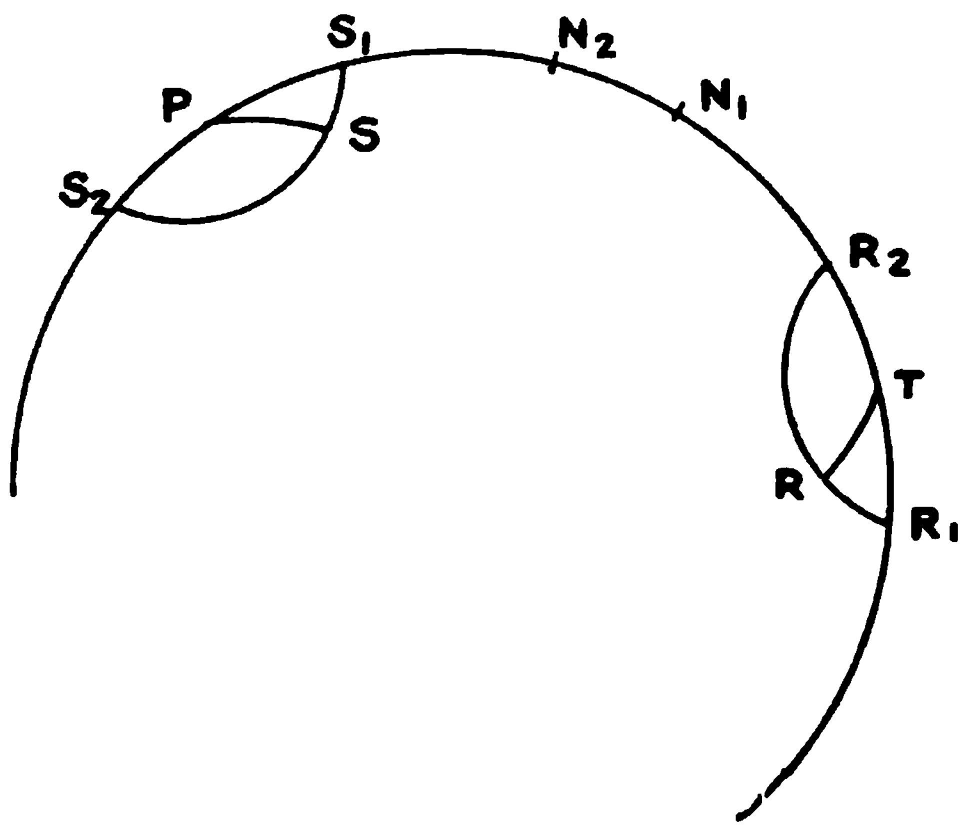


FIG. 1.

3. Its motion is given by the equation

$$\tan \tfrac{1}{2}\mathrm{RTR}_1 = \mathrm{K} \tan \tfrac{1}{2}\mathrm{SPS}_1 \quad \ldots \quad \ldots \quad (1)$$

where K is a constant depending simply on the distances PS and PT. If PS $=\delta$ and PT $=\rho$, then M. Cornu shows* that

$$\mathrm{K} = \frac{\cos \tfrac{1}{2}(\rho+\delta)}{\cos \tfrac{1}{2}(\rho-\delta)} \quad \ldots \quad \ldots \quad \ldots \quad (2)$$

Thus when $\mathrm{SPS}_1 = 0°$ or $180°$, $\mathrm{RTR}_1 = 0°$ or $180°$, but for intermediate values the angles differ. [For the cœlostat $\rho+\delta = 180°$; hence $\mathrm{K}=0$ and $\mathrm{RTR}_1 = 0°$ permanently, except when $\mathrm{SPS}_1 = 180°$. This case is more particularly referred to in § 12.]

4. Now the motion of TR defines the rotational motion required. If we suppose a photographic plate pivoted at T, and moving round T as if TR were rigidly attached to the plate, then all the rest of the picture will remain fixed relatively to the plate, which is the condition required for photography. We proceed to consider various mechanical ways of securing this motion.

5. *First Device.*—If S and C be fixed points, and PN a fixed line at right angles to them on which the point P moves, then

* M. Cornu finds the reciprocal of this expression; but I think there is an algebraical slip in passing from one equation to the other on p. 151 *loc. cit.*

$$\tan \mathrm{PSN} = \frac{\mathrm{PN}}{\mathrm{SN}}$$
$$= \frac{\mathrm{CN}}{\mathrm{SN}} \cdot \frac{\mathrm{PN}}{\mathrm{CN}}$$

or
$$\tan \mathrm{PSN} = \frac{\mathrm{CN}}{\mathrm{SN}} \tan \mathrm{PCN} \quad \ldots \quad \ldots \quad (3)$$

Thus, if
$$\frac{\mathrm{CN}}{\mathrm{SN}} = \mathrm{K} = \frac{\cos \frac{1}{2}(\rho+\delta)}{\cos \frac{1}{2}(\rho-\delta)} \quad \ldots \quad \ldots \quad (4)$$

and if the angle PCN is made the same as $\frac{1}{2}\mathrm{SPS}_1$ in equation (1), and therefore increases uniformly with the time, then PSN will be the same as $\frac{1}{2}\mathrm{RTR}_1$, and we have only to make another line move at twice the rate of SP.

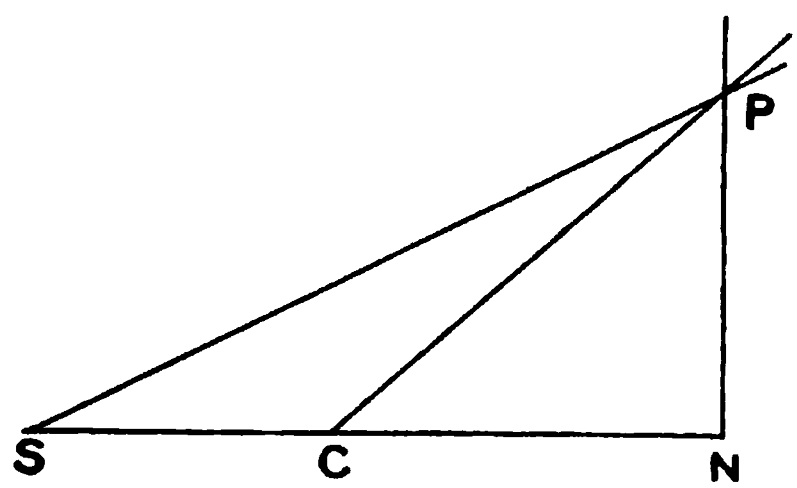


FIG. 2.

Mechanically, SCN and NP must be two bars, PN being grooved. CP and SP must be bars pivoted at S and C, and also grooved; and a pin, P, must connect all three together. CP is to be rotated uniformly by clockwork once in two days, and then SP will move nearly as required. To complete the apparatus we must make another bar or wheel move just twice as fast as SP, which can be done in a variety of ways—*e.g.* by cog-wheel gearing in the ratio of 2 to 1.

6. *Second Device.*—The equation

$$\tan \theta = \mathrm{K} \tan nt \quad \ldots \quad \ldots \quad \ldots \quad (5)$$

is really a particular case of epicyclical motion. Let a point A (fig. 3) be revolving uniformly round a point O at unit distance from it, so that its coordinates may be written

$$x = \cos u \qquad y = \sin u.$$

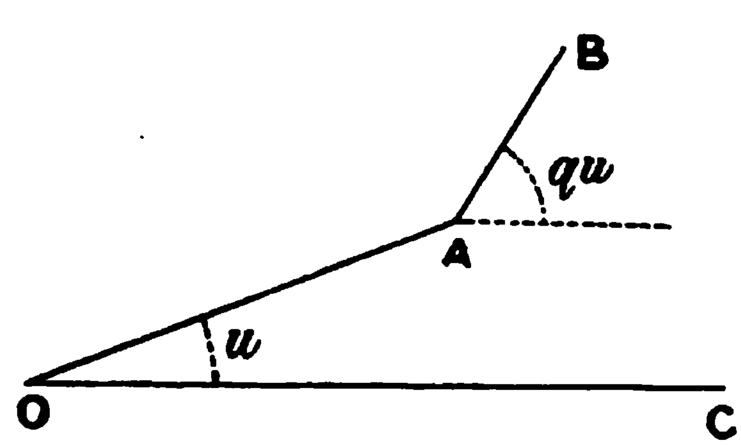


FIG. 3.

Let a second point, B, be revolving uniformly about A, so that its coordinates *referred to* A are

$$x' = p\cos qu \qquad y' = p\sin qu.$$

Then the coordinates of B with respect to O will be

$$x + x' = \cos u + p\cos qu \qquad y + y' = \sin u + p\sin qu\,;$$

and the direction θ in which B is seen from O is given by the familiar equation

$$\tan\theta = \frac{y+y'}{x+x'} = \frac{\sin u + p\sin qu}{\cos u + p\cos qu} \quad \ldots \quad \ldots \quad (6)$$

This is the general equation for epicyclical motion.

7. If $q = -1$, we have

$$\tan\theta = \frac{\sin u - p\sin u}{\cos u + p\cos u} = \frac{1-p}{1+p}\tan u \quad \ldots \quad (7)$$

which resembles equations (1), (3), (5).

In this case the two revolutions are performed in the same period in opposite directions, and the curve is easily seen to be an ellipse.

For the coordinates of B are

$$x + x' = (1+p)\cos u$$

and
$$y + y' = (1-p)\sin u,$$

which represent an ellipse, axes $2(1+p)$ and $2(1-p)$.

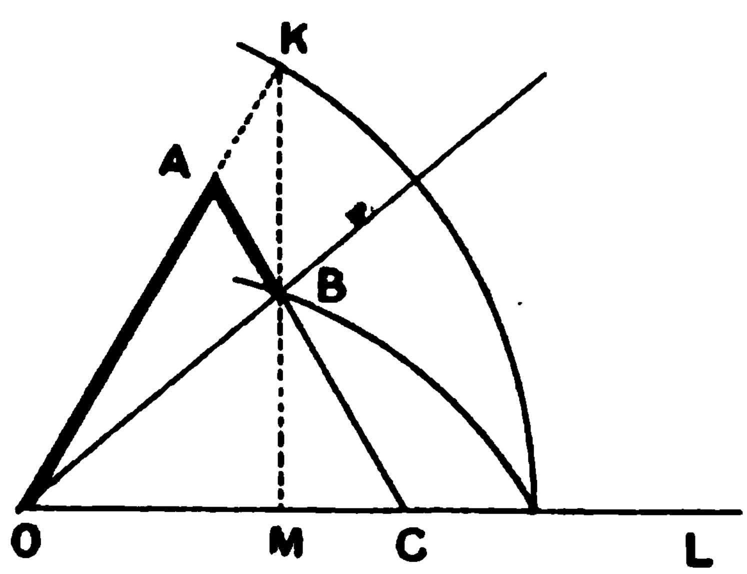


Fig. 4.

Thus let OA, AC be two equal bars, and let OA describe a circle round O uniformly, and let AC be pivoted at A, and the point C constrained to move along the line OL, so that OAC is an isosceles triangle, and AC revolves round A uniformly at the same pace as AO round O, but in the opposite direction. Then any point B on AC, where

$$AB = p\,.\,OA,$$

describes an ellipse; and further, if a bar, OB, be freely pivoted at O and constrained to pass through B, it will move so that

$$\tan \mathrm{BOL} = \frac{1-p}{1+p} \tan \mathrm{AOL} \quad \ldots \quad \ldots \quad (8)$$

It is easily seen that if OA be produced to K, where

$$\mathrm{AK} = \mathrm{AB},$$

then K lies on the ordinate MB, and also on the auxiliary circle; and equation (8) is only another form of the well-known relation

$$\mathrm{KM} : \mathrm{BM} = 1 + p : 1 - p,$$

i.e. in the ratio of the semi-axes.

8. These properties indicate a simple form of ellipsograph, which is probably not new,* but which I do not happen to have seen. It is, however, closely related to an ordinary form. If OL and ON be two fixed bars at right angles, and CD be a bar of constant length whose ends, C, D, slide on OL and ON respectively, then any point B on CD is known to describe an ellipse. If A be the middle point of CD, then OA=AC=AD,

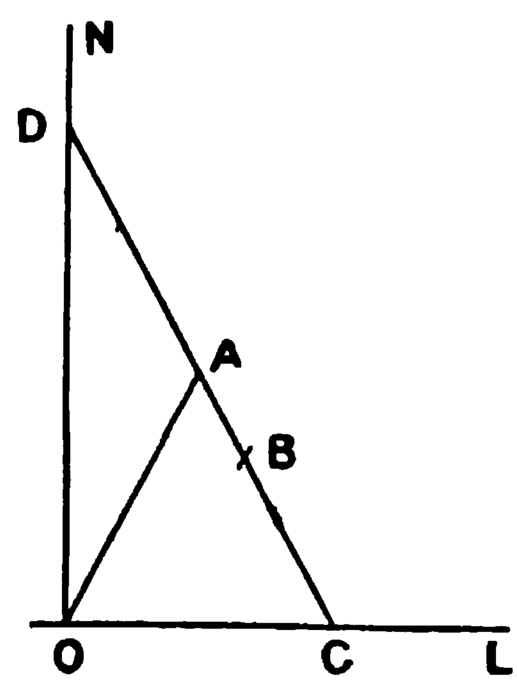


FIG. 5.

and is of constant length; and we may remove the portion AD if we tie A to O by a bar, which gives the above construction.

9. Having secured the motion of the bar OB so as to satisfy the equation

$$\tan \mathrm{BOL} = \frac{1-p}{1+p} \tan \mathrm{AOC},$$

it remains only to make the bar AO revolve once in two days, as

* Mr. Wesley, after the reading of this paper, drew my attention to the fact that this form of ellipsograph has been described by Mr. Burnham in *Popular Astronomy*, vol. iv. p. 181.

in the first device, and to attach a cog-wheel or other arrangement to OA, so as to double its angular motion. The advantage of this arrangement over the first is that all the bars remain of constant length. In fig. 2 it will be seen that as P travels up NP the bars SP and CP must be longer and longer; and indeed *complete* motion with the first arrangement is impossible. Since we should in practice, however, usually be working near the meridian of the telescope, the first device might be found useful in spite of its disadvantages.

10. *Third Device.*—But there is a third arrangement which is prettier (geometrically) than either. In both the former devices we have had to multiply the movement by 2, by a pair of cog-wheels or some other multiplying arrangement. In fact, we have considered the equation

$$\tan\theta = K \tan nt \quad \dots \quad \dots \quad (9)$$

rather than the equation

$$\tan\tfrac{1}{2}\theta = K \tan\tfrac{1}{2}nt \quad \dots \quad \dots \quad (10)$$

But equation (10) is a familiar one. It represents motion about the focus of an ellipse just as equation (9) represents motion about the centre. In "Dynamics of a Particle" we have the equation

$$\tan\tfrac{1}{2}\theta = \sqrt{\frac{1-e}{1+e}} \cdot \tan\tfrac{1}{2}u \quad \dots \quad (11)$$

where u is the eccentric anomaly, and θ the true anomaly. Thus in fig. 6 let, as before, two equal bars OA, AC be pivoted at O and A, and let C be free to slide along SOL. Then any point B in AC will describe an ellipse. Let S be the focus of this ellipse, and let a bar pivoted at S be constrained to pass through B. Then it will move in the required manner *without* any multiplying device, if OA revolve uniformly *once* a day. I think this seems the best way of mechanically compensating the rotation.

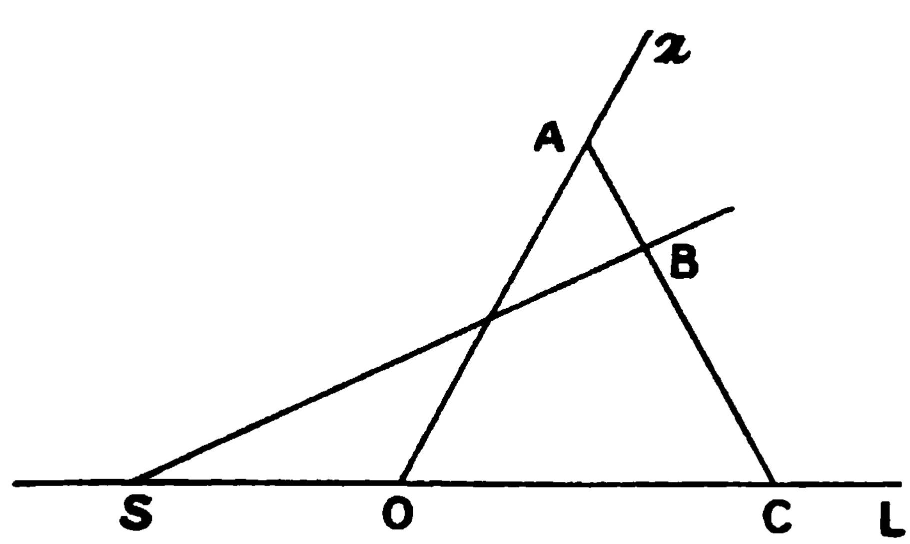


FIG. 6.

11. As regards details, since the unit of length is arbitrary, let us first consider keeping the points O and S fixed. There is

a convenience about this, since S is practically the centre of the plate. The pivot at A must then be altered, and the length of AC adjusted, as well as the point B, to suit the particular star. It seems better to keep OA and AC fixed, and to adjust B and S. To find their positions we have

$$\sqrt{\frac{1-e}{1+e}}=\mathrm{K}=\frac{\cos \frac{1}{2}(\rho+\delta)}{\cos \frac{1}{2}(\rho-\delta)} \quad \ldots \quad \ldots \quad \ldots \quad (12)$$

$$\therefore \quad \frac{1-e}{1+e}=\frac{(1+\cos \rho \cos \delta)-\sin \rho \sin \delta}{(1+\cos \rho \cos \delta)+\sin \rho \sin \delta}$$

or

$$e=\frac{\sin \rho \sin \delta}{1+\cos \rho \cos \delta} \quad \ldots \quad \ldots \quad \ldots \quad (13)$$

Further, if $AB=p \,.\, AO$, the axes are $1+p$ and $1-p$; or

$$(1+p)^2(1-e^2)=(1-p)^2$$

or

$$e^2=\frac{4p}{(1+p)^2} \quad \ldots \quad \ldots \quad (14)$$

Hence, $p=2-e^2+2\sqrt{1-e^2}=(1+\sqrt{1-e^2})^2 \quad \ldots \quad \ldots \quad (15)$

and $OS=e(1+p)=2\sqrt{p}=2+2\sqrt{1-e^2} \quad \ldots \quad \ldots \quad \ldots \quad (16)$

12. *The Cœlostat.*—The particular case of the Cœlostat deserves notice. In § 2 it was remarked that the reflected image R of the Pole always describes a circle about T of radius equal to PS—*i.e.* of finite radius, depending only on the star. And yet in the Cœlostat we know that the image of the Pole, like every other point of the sky, remains fixed. How is this apparent paradox to be explained? The above construction shows the way in which it occurs as a limiting case. The limit is when $\cos \frac{1}{2}(\rho+\delta)=0$, and $e=1$. The ellipse thus becomes a parabola, and S is at an infinite distance.

But suppose that, as suggested in the beginning of the last paragraph, we keep the length OS constant, and vary OA and AC. As e approaches unity, p approaches unity—*i.e.* B approaches very near to C; and its motion becomes nearly the same as that of C—*i.e.* it travels nearly along the straight line LO. Thus SB remains nearly coincident with SC, *until* B gets near S. Then SB travels very swiftly round through nearly 360°, and comes to approximate coincidence with SC, but on the other side.

Thus the limiting case of the cœlostat is one in which the plate remains fixed for the whole twenty-four hours less one instant, in which time it suddenly makes a complete revolution. The arc TR still describes its circle, but in *no time*.

It will now be clear how the cœlostat occupies the position of transition between cases where TR describes its circle in opposite directions. The revolution in *no time*—*i.e.* with infinite velocity—may be performed indifferently in either direction

just as asymptotes meet a curve at infinity in either direction. If this explanation is correct, the case is a curiosity which has (so far as I know) hitherto escaped attention.

Observations of Saturn made at Juvisy Observatory in 1900.

By C. Flammarion.

The planet was observed from July to October last, and, although the number of clear nights was abnormally great, definition was seldom satisfactory.

The instrument employed was the $9\frac{1}{4}$-inch equatorial, bearing negative eyepieces magnifying 218, 300, 400, and 600 diameters, the observers being M. Antoniadi and myself.

1. *The Globe.*

The N. polar cap was not very dark in 1900. No certain traces of the N. temperate band were seen. The great double tropical belt was, however, a very striking feature of the planet, its duplex character being recognised under almost any kind of definition—even when the Cassini division was invisible.* The dark spots occasionally found on this belt were much better seen in 1900 than in 1899. Thus, one of them, having a condensation on each of the components of the belt, was seen in transit over the central meridian on 1900 July $15^d\ 11^h\ 10^m$ G.M.T. Another, much more marked spot, but having no condensation on the N. branch, was central on September $5^d\ 7^h\ 41^m$; and a third, double spot, on September $5^d\ 8^h\ 33^m$. By far the brightest, though yellowest, portion of the globe was the equatorial zone. It was very uneven in tint, and mottled in appearance. A faint dusky band, almost marking the equator, was seen with certainty on July 10 and September 5.

The decreasing luminosity of the globe towards the limb was very marked.

2. *The Rings.*

(*a*) *Outer Ring, A.*—Encke's division could never be seen, though carefully looked for. The indentations along the ansæ, near Cassini's division, were easily seen, and have been noted on many occasions in 1900. As far as could be judged, their structure was triangular; one side of each triangle resting on the inner edge of this Ring.

As usual, Cassini's division seemed grey and not black. Probably there is some matter in it. In fact, Maxwell has shown that the collisions among the particles would tend to widen the several rings. The division seemed still tangent to the globe,

* Dr. Deslandres was recently successful in photographing the double belt with the great 23·6-inch photographic equatorial of Meudon.

though the presence of the planet's shadow rendered this observation rather difficult.

(*b*) *Inner Bright Ring, B.*—This has been invariably destitute of detail, the gradations shown by Trouvelot being quite invisible in 1900, though they have been so marked in the last few years. But the inner edge of B was exceedingly indefinite, and at times it was impossible to say where the bright ring ended and where the "dark" began.

(*c*) *The "Crape" Ring, C.*—This was fainter than usual along the ansæ, an effect due, very likely, to the low altitude of the planet. On October 2 the appearance described on pp. 21–22 of the present volume, and now given in the annexed fig. 1, was

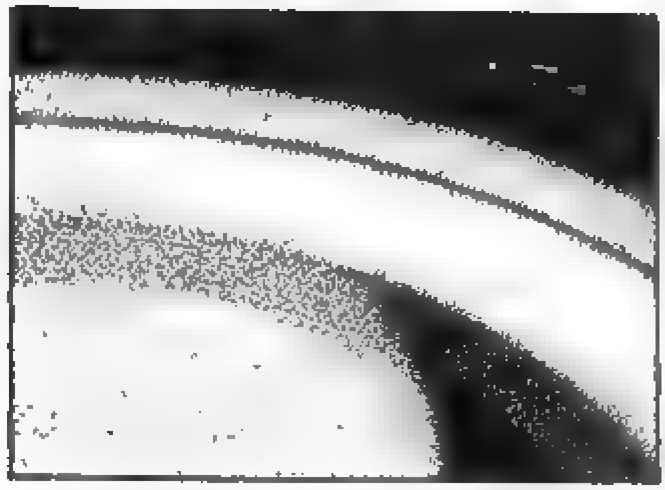


Fig. 1. Appearance of the "Crape" Ring on 1900 October 2.

detected easily, when the part of the "Crape" Ring across the globe did not seem to have its inner edge in continuation of the part projected on the sky.

The shadow of the planet had an irregular outline owing to the varying luminosity of the Ring (fig. 2). Irradiation caused

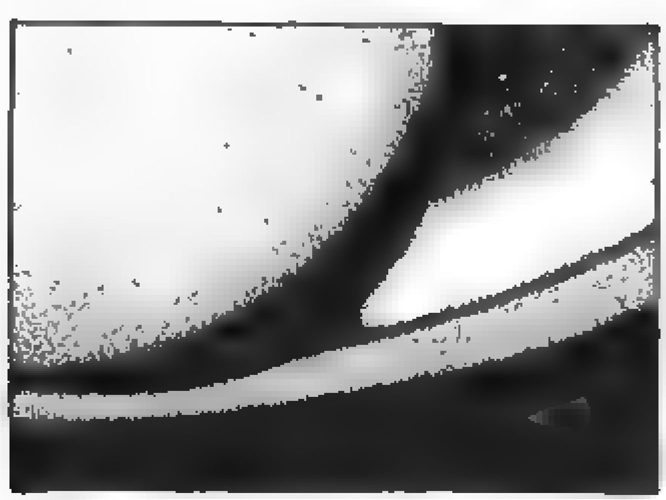


Fig. 2. Irregularity in the planet's shadow, due to irradiation.

it to appear to turn round in a sharp curve into the Cassini division.

Lastly, as in previous years, the eastern vacuity between *Saturn* and the Ring seemed greater than the western, the effect being very marked indeed in 1900.

Note on the Rotation Period of Saturn in 1896 *and* 1897.
By C. Flammarion.

Systematic observations of *Saturn* were started here in 1894, and since that time the work has been carried on to the present year.

In 1894 very few details were seen on the globe, and the double structure of the great dusky belt north of the equatorial zone was scarcely recognised. No spots, dark or white, were seen at that time.

In 1895 the planet was seen much better. The duplicity of the north equatorial belt was well marked, while the narrow band marking the equator was also an obvious feature. On 1895 July 8 a very small dark spot was seen on this band, transiting the central meridian at 9^h G.M.T. This marking was well suited for getting a very accurate determination of the rotation period of the material very near the equator; but it was never seen again.

On 1896 June 27 M. Antoniadi, by stopping down the aperture of the $9\frac{3}{4}$ inch equatorial to $6\frac{1}{2}$ inches, detected a faint dusky spot on the great belt; it was double, having a condensation on each of the two components of the belt. A fainter single spot was seen meantime preceding by a few minutes the double spot. Since that time the dark spots of *Saturn* were easily seen whenever the atmospheric conditions were not very unfavourable.

A thorough discussion of the observations gives the following results :—

Three of the dark spots seen in 1896 could be followed through several transits over the central meridian.

Spot.	First seen.	Last seen.	No. of Rotations.	Rotation Period. h	m	s
1896 A	June 27	July 6	21	10	13	58·0
„ B	„ 27	„ 11	33	10	14	39·6
„ C	„ 29	„ 11	28	10	14	4·1
	Mean period of rotation	...	...	10	14	14·

In 1897 the dusky spots were very easy objects, and a great number of them have been seen by myself and other observers.

Four spots could be followed through more than one transit.

Spot.	First seen.	Last seen.	No. of Rotations.	Rotation Period. h	m	s
1897 A	June 13	August 19	157 *	10	14	0·6
„ B	July 10	July 18	19	10	13	23·3
„ C	„ 10	„ 16	14	10	14	15·2
„ D	„ 10	„ 16	14	10	14	36·6
	Mean period of rotation	...	..	10	14	4·

It became increasingly difficult to see the spots, as the southern declination of *Saturn* increased in 1898, 1899, and 1900, and the rarity with which they were seen stood in the way of any serious identification of them. The results, however, for 1896 and 1897 are satisfactory for $+18°$ of kronocentric latitude, and in fair agreement with the work of other observers.

On the Accuracy of Eye-observations of Meteors and the Determination of their Radiant Point. By Bryan Cookson.

The probable existence of stationary radiants for so many meteoric showers and the difficulty of finding a satisfactory physical explanation of them, makes the question of the determination of the radiant of considerable importance. The following is an attempt to obtain a numerical estimate of the accuracy of eye-observations of meteors. So far only *Perseids* have been used for the purpose, this being the shower which afforded the largest number of bright and easily observed meteors; but it would be interesting to apply the method to other showers with different characteristics, such as those of April and October.

A chart of the celestial sphere on the gnomonic projection was drawn on a scale of about $\frac{1}{10}$-inch to 1° R.A., and $\frac{1}{5}$-inch to 1° Decl., with centre at R.A. 45°, Decl. $+57°$, which is the assumed position of the *Perseid* radiant on August 10. From the recorded R.A. and Decl. of beginning and end, the paths of the meteors were drawn upon tracing paper placed on the chart, and the equation of the line of the meteor referred to rectangular coordinates, with their origin at R.A. 45°, Decl. $+57$, was found graphically by an easy and rapid method in the form

$$x \cos a + y \sin a - p = 0.$$

The radiant is the point such that the sum of the squares of the perpendiculars from it to these lines is a minimum. We have, therefore, to solve by least squares a system of equations of the above form for x and y, which are small corrections to be applied to the approximate radiant.

* The identity of the spots seen on 1897 June 13 and August 19 is somewhat doubtful, as there are no intermediate observations.

Weights have been assigned to the equations based upon the following considerations. It is assumed that for a given observer an error in the recorded beginning or end of a meteor's path is equally probable in any direction. This is not, however, strictly true: Professor Weiss found that the probable error of a recorded beginning or end was about $\pm 2°\cdot 95$, but that the direction of path was more accurate than this large error would lead one to expect. This is owing to the fact that many observers record the end of a trail in the prolongation of the meteor's path, and hence by comparing observations of the same meteors by different observers the differences in the celestial coordinates of the end may be considerable, whilst the direction of the path may be very nearly the same for all. The probable error as far as direction is concerned was found to be $\pm 1°\cdot 0$ (*Sitzungsber. Wien Akad.* vol. 62 Abt. II. pp. 277–344). As we are here only concerned with direction, it seems legitimate to make the above assumption.

Let then a small arc ρ of great circle be resolved into two perpendicular components: to find the mean error of these components ϵ_1 and ϵ_2, corresponding to a mean error ϵ of ρ, we have

$$\epsilon_1^2 = \frac{\epsilon^2}{2\pi}\int_0^{2\pi} \cos^2 \psi d\psi = \frac{\epsilon^2}{2} \ : \ \epsilon_2^2 = \frac{\epsilon^2}{2\pi}\int_0^{2\pi} \sin^2 \psi d\psi = \frac{\epsilon^2}{2}\,.$$

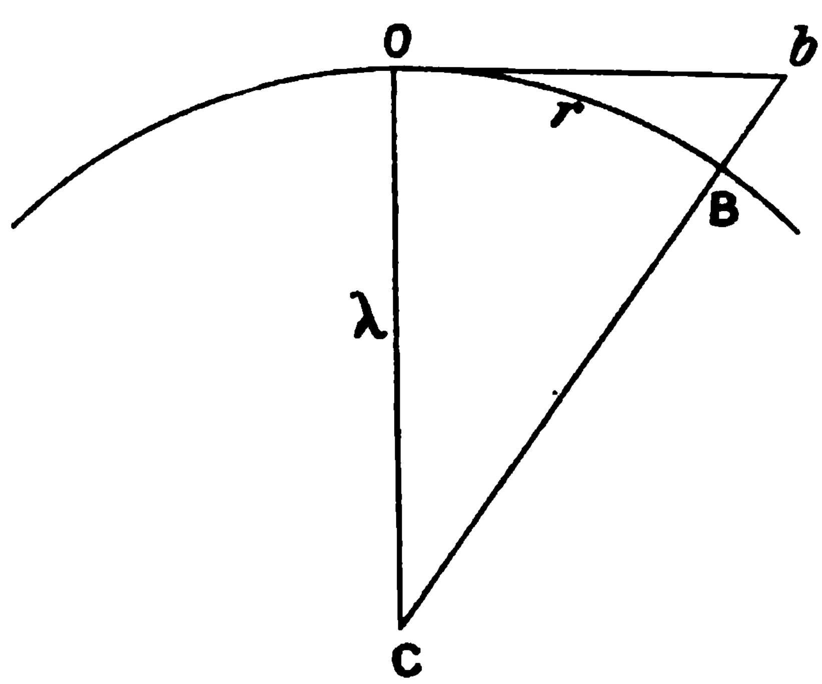
The mean error of the components is therefore $\frac{\epsilon}{\sqrt{2}}$.

If now B be projected into b, the coordinates of b are

$$x = \lambda \tan r \cos \theta$$
$$y = \lambda \tan r \sin \theta\,.$$

The small displacements of B in perpendicular directions are clearly

$$dr \text{ and } \sin r \,.\, d\theta\,,$$



and we have just seen that the mean error of each is $\epsilon/\sqrt{2}$.

But it is known that if a linear differential relation such as

$$dP = A\,dx + B\,dy + C\,dz + \ldots$$

holds good, then

$$\epsilon_P^2 = A^2\epsilon_x^2 + B^2\epsilon_y^2 + C^2\epsilon_z^2 + \ldots$$

where ϵ_P denotes the mean error of P, &c. In our case we have

$$dx = \lambda \sec^2 r \cos\theta\, dr - \lambda \tan r \sin\theta \frac{1}{\sin r}(\sin r\, d\theta),$$

and therefore

$$\begin{aligned}
\epsilon_x^2 &= \lambda^2 \sec^4 r \cos^2\theta \frac{\epsilon^2}{2} + \lambda^2 \tan^2 r \sin^2\theta \frac{1}{\sin^2 r}\frac{\epsilon^2}{2} \\
&= \frac{\epsilon^2}{2}\lambda^2 \sec^2 r\left[(1+\tan^2 r)\cos^2\theta + \sin^2\theta\right] \\
&= \frac{\epsilon^2}{2}(\lambda^2 + x^2 + y^2)\left(1 + \frac{x^2}{\lambda^2}\right) \\
&= \frac{\epsilon^2}{2}\frac{(\lambda^2+\rho^2)(\lambda^2+x^2)}{\lambda^2}
\end{aligned}$$

Similarly,

$$dy = \lambda \sec^2 r \sin\theta\, dr + \lambda \tan r \cos\theta \frac{1}{\sin r}(\sin r\, d\theta)$$

and

$$\begin{aligned}
\epsilon_y^2 &= \frac{\epsilon^2}{2}\lambda^2 \sec^2 r\left[(1+\tan^2 r)\sin^2\theta + \cos^2\theta\right] \\
&= \frac{\epsilon^2}{2}\frac{(\lambda^2+\rho^2)(\lambda^2+y^2)}{\lambda^2}.
\end{aligned}$$

I am indebted to Professor Turner for pointing out this method of deducing the expressions for ϵ_x and ϵ_y; it leads to the same results but is much shorter and more elegant than that originally used by me.

Now, since in the equations of condition $x\cos\alpha + y\sin\alpha - p = 0$ x and y are small quantities, we may neglect the mean errors of $\cos\alpha$ and $\sin\alpha$, and consider the weight of the equation as proportional to the square of the mean error of the absolute term, p.

Let, therefore, x_1y_1 be the coordinates of the beginning of the meteor's path, and x_2y_2 those of the end.

Then

$$p = \frac{y_2x_1 - y_1x_2}{\{\overline{x_2 - x_1}^2 + \overline{y_2 - y_1}^2\}^{\frac{1}{2}}} = \frac{y_2x_1 - y_1x_2}{D}$$

$$\therefore\ dp = \frac{1}{D}\left\{ y_2+\frac{p}{D}(x_2-x_1)\right\} dx_1 - \frac{1}{D}\left\{ y_1+\frac{p}{D}\overline{x_2-x_1}\right\} dx_2$$
$$-\frac{1}{D}\left\{ x_2-\frac{p}{D}(y_2-y_1)\right\} dy_1 + \frac{1}{D}\left\{ x_1-\frac{p}{D}\overline{y_2-y_1}\right\} dy_2$$
$$= \frac{1}{D}\left\{ y_2-p\sin\alpha\right\} dx_1 \quad -\frac{1}{D}\left\{ y_1-p\sin\alpha\right\} dx_2$$
$$-\frac{1}{D}\left\{ x_2-p\cos\alpha\right\} dy_1 \quad +\frac{1}{D}\left\{ x_1-p\cos\alpha\right\} dy_2$$
$$= -\frac{1}{D}\sqrt{\rho_2{}^2-p^2}\ .\ \cos\alpha\ .\ dx_1 + \frac{1}{D}\sqrt{\rho_1-p^2}\ .\ \cos\alpha\ dx_2$$
$$-\frac{1}{D}\sqrt{\rho_2{}^2-p^2}\ \ \sin\alpha\ .\ dy_1 + \frac{1}{D}\sqrt{\rho^2-p^2}\ .\ \sin\alpha\ .\ dy_2.$$

Hence,

$$\epsilon_p{}^2 = \frac{1}{D^2}\left[\cos^2\alpha\left\{(\rho_2{}^2-p^2)\epsilon^2{}_{x_1} + (\rho_1{}^2-p^2)\epsilon^2{}_{x_2}\right\} + \sin^2\alpha\left\{(\rho_2{}^2-p^2)\epsilon^2{}_{y_1} + (\rho_1{}^2-p^2)\epsilon^2{}_{y_2}\right\}\right]$$

or

$$\epsilon_p{}^2 = \frac{\epsilon^2}{2}\frac{1}{\lambda^2 D^2}\left[(\lambda^2+\rho_1{}^2)(\rho_2{}^2-p^2)(\lambda^2+x_1{}^2\cos^2\alpha+y_1{}^2\sin^2\alpha) + (\lambda^2+\rho_2{}^2)(\rho_1{}^2-p^2)(\lambda^2+x_2{}^2\cos^2\alpha+y_2{}^2\sin^2\alpha)\right]$$
$$= \frac{\epsilon^2}{2}\frac{1}{\lambda^2 D^2}\left[(\lambda^2+p^2)\left\{(\lambda^2+\rho_1{}^2)(\rho_2{}^2-p^2)+(\lambda^2+\rho_2{}^2)(\rho_1{}^2-p^2)\right\} - 2\sin\alpha\cos\alpha\left\{x_1y_1(\lambda^2+\rho_1{}^2)(\rho_2{}^2-p^2)+x_2y_2(\lambda^2+\rho_2{}^2)(\rho_1{}^2-p^2)\right\}\right]$$
$$= \frac{\epsilon^2}{2}\frac{1}{\lambda^2 D^2}\left[(\lambda^2+p^2)P - 2\sin\alpha\cos\alpha\ Q\right],\ \text{suppose.}$$

The scale of projection used is such that $\lambda = 10$ inches; the mean value of p is then about $\cdot 5$, and of ρ_1 about 3; hence, excepting in a very few cases where ρ_1 is small ($<$ 1), that is when the meteor starts from very near the radiant, it is safe to neglect p^2 and take

$$P = \rho_1{}^2(\lambda^2+\rho_2{}^2) + \rho_2{}^2(\lambda^2+\rho_1{}^2).$$

If $\theta_1\theta_2$ are the angles which the lines joining the beginning x_1y_1 and end x_2y_2 of the meteor's path make with the axis of x, then

$$\frac{x_1y_1}{\rho_1{}^2} = \tfrac{1}{2}\sin 2\theta_1 \qquad \frac{x_2y_2}{\rho_2{}^2} = \tfrac{1}{2}\sin^2\theta_2$$
$$\therefore\ \frac{x_1y_1}{\rho_1{}^2} - \frac{x_2y_2}{\rho_2{}^2} = \sin(\theta_1-\theta_2)\cos(\theta_1+\theta_2)$$
$$= \left(\frac{y_1}{\rho_1}\frac{x_2}{\rho_2} - \frac{y_2}{\rho_2}\frac{x_1}{\rho_1}\right)\cos(\theta_1+\theta_2)$$
$$= -\frac{pD}{\rho_1\rho_2}\cos(\theta_1+\theta_2)$$

Thus

$$Q=x_1y_1\Big[(\lambda^2+\rho_1^2)(\rho_2^2-p^2)+\frac{\rho_2^2}{\rho_1^2}(\lambda^2+\rho_2^2)(\rho_1^2-p^2)\Big]$$
$$+\frac{pD\rho_2}{\rho_1}\cos(\theta_1+\theta_2)(\lambda^2+\rho_2^2)(\rho_1^2-p^2)$$

In an unfavourable case we might have $x_1=y_1=2$; $p=\frac{1}{2}$, $\rho_1=2\sqrt{2}$, $\rho_2=3\sqrt{2}$, $D=\sqrt{2}$; the ratio of the last two terms in Q is then at most

$$4\cdot\frac{9}{4}:\frac{1}{2}\sqrt{2}\cdot\frac{3}{2}\text{ or nearly }8:1.$$

We are therefore justified in neglecting the last term as well as p^2 in the first two terms; and a table of values of P and Q′ where

$$Q'=\rho_1^2\rho_2^2(2\lambda^2+\rho_1^2+\rho_2^2)$$

was constructed.

The coefficient of Q′ is $-2\sin\alpha\cos\alpha\frac{x_1y_1}{\rho_1^2}$ and is always positive; the value of x_1y_1/ρ_1^2 or $\frac{1}{2}\sin 2\theta_1$ can easily be read off to two decimal places by placing a piece of tracing paper on the chart having lines ruled, along which $\frac{1}{2}\sin 2\theta_1$ has the values 0·1 to 0·5.

The weight of an equation is inversely proportional to the square of the mean error of its absolute term, and in the present case the weight is therefore proportional to

$$\frac{\lambda^2D^2}{\lambda^2P+2\sin\alpha\cos\alpha\frac{x_1y_1}{\rho_1^2}Q'}$$

which is the simplest form to which the expression for the weight can be reduced. The numerical value of D is found by means of a foot rule, P and Q′ are taken together out of the table; x_1y_1/ρ_1^2 is read off graphically, and $2\sin\alpha\cos\alpha$ is twice the product of the coefficients of x and y. No attention has to be paid to signs. For convenience the weights are multiplied by 100.

The table of P and Q′ which was actually used is here given; the values of Q′ are printed in italics immediately beneath the corresponding values of P.

Let g be the weight of an equation (m in number),

v be a residual—*i.e.* the perpendicular from the deduced radiant on the meteor's path.

Then the mean error of an absolute term whose weight is unity is

$$\sqrt{\frac{[gvv]}{m-2}}.$$

TABLE OF P AND Q′.

$$P = \rho_1^2(1+\rho_2^2) + \rho_2^2(1+\rho_1^2) \text{ and } Q' = \rho_1^2\rho_2^2(1+\rho_1^2+1+\rho_2^2)$$

$r_1 \rightarrow$ / $r_2 \downarrow$	·05	·10	·15	·20	·25
·10	·01	↓	·15		
	...				
1·05	$p =$ ·10,	”	·02	”	
1·10	$p =$ ·11,	”	·02	”	
1·15	$p =$ ·12,	”	·03	”	
1·20	$p =$ ·13,	”	·03	”	
1·25	$p =$ ·14,	”	·04	”	
1·30	$p =$ ·15,	”	·04	”	
1·35	$p =$ ·16,	”	·05	”	
1·40					
1·45					
1·50					

·30	·35	·40	·45	·50	·55	·60	·65	·70	·75	·80	·85	·90
						[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	3·10	
						1·18	1·45	1·71	2·00	2·33	2·69	
					1·05	2·21	2·44	2·67	2·90	3·14	3·40	
						1·33	1·64	1·94	2·26	2·63	3·04	
					1·10			2·88	3·13	3·39	3·67	3·98
								2·19	2·56	2·98	3·44	3·94
						1·15		3·09	3·36	3·64	3·94	4·27
								2·43	2·88	3·35	3·85	4·42
							1·20		3·60	3·92	4·24	4·59
									3·20	3·76	4·33	4·97
								1·25		4·20	4·52	4·89
										4·19	4·84	5·51
								1·30			4·85	5·24
											5·38	6·16
								1·35			5·16	5·57
											5·95	6·81
								1·40				5·95
												7·58
								1·45				6·31
												8·35

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The mean error of an absolute term of weight g, or of an observed p, is therefore

$$\frac{1}{\sqrt{g}}\sqrt{\frac{[gvv]}{m-2}}.$$

But we have just found that this was ϵ_p, where

$$\epsilon_p^2=\frac{\epsilon^2}{2}\frac{1}{\lambda^2 D^2}\left\{\lambda^2 P+2\sin a\cos a\frac{x_1 y_1}{\rho_1^2}Q'\right\}$$

and we have taken

$$g=100\frac{\lambda^2 D^2}{\lambda^2 P^2+2\sin a\cos a\frac{x_1 y_1}{\rho_1^2}Q}.$$

Hence

$$\frac{1}{\sqrt{g}}\sqrt{\frac{[gvv]}{m-2}}=\epsilon_p=\frac{\epsilon}{\sqrt{2}}\frac{10}{\sqrt{g}},\text{ or }\epsilon=\tfrac{1}{10}\sqrt{\frac{2}{m-2}[gvv]}.$$

Now g is of -2 dimensions in length, and ϵ is therefore a number, and is the circular measure of the arc of great circle, which is the mean error of an observed beginning or end of a meteor's path.

The effect of zenith attraction, rotation and orbital motion of the Earth have been neglected as inappreciable. For let ξ, η be the coordinates of the apparent radiant referred to parallel axes through the unknown true radiant; let x, y be the coordinates of the true radiant. Then ξ, η are known at any moment, when the character of the swarm is known. The perpendicular distance from the point $x+\xi$, $y+\eta$ on to the line of a meteor's track is

$$(x+\xi)\cos a+(y+\eta)\sin a-p=0.$$

The error committed in neglecting ξ, η is therefore

$$dp=\xi\cos a+\eta\sin a,$$

of which the maximum value is $\sqrt{\xi^2+\eta^2}$, when $\tan \dot{a}=\eta/\xi$. From Dr. Kleiber's table in *Monthly Notices*, lii. p. 352, we find that, to reduce observations made on a given night to the midnight of that night, we must apply the following corrections:—

	Δa	$\Delta\delta$	ξ	η	$\sqrt{\xi^2+\eta^2}$
	°	°			
9 P.M.	−0·40	+0·71	−·38	+1·24	1·3
Midnight	−0·71	+0·49	−·67	+ ·89	1·1
3 A.M.	−0·63	+0·24	−·59	+ ·42	0·7

The unit of p was for convenience always taken as $\frac{1}{10}$ inch; x, y, ξ, η are also expressed in terms of this unit. As the probable error of x and y generally amounts to about $\pm 0·5$, it will be quite

sufficient to apply the mean correction $\xi = -0{\cdot}5$, $\eta = +1{\cdot}0$ to the values of x and y, deduced from meteors fairly evenly distributed in time from 9 P.M. to 3 A.M., in order to get the absolute place at midnight. Had these disturbing causes produced appreciable effects, the path of the apparent radiant should be drawn round the origin as true radiant, and p measured from the point on this curve corresponding to the time of observation instead of from the origin. In the case of the *Perseids* this point does not appreciably shift during the night.

The observations discussed so far are :—

		Meteors.	
W. F. Denning at Bristol		149	Communicated in manuscript.
M. Morine	Poulkova	49	"Sur les Perséids, observées en 1890." (*Brédikhine, Bull. St. Pét. Acad.* 1894, No 1.)
M. Maggi	Volpeglino	46	*Pub. Osservatorio di Brera*, No. 7, p. 58.
M. Scharbe	Dorpat	43	*Astr. Nach.* Bd. 149, p. 213.
M. Lewitsky	Dorpat	23	" " " "
	Total ...	310	

Mr. Denning very kindly copied out some of his observations of *Perseids* and sent them to me at my request. I am much indebted to him for having done this.

The results from these observations are as follows :—

Observer.	Date. August.	r. Probable Error of p of weight unity.	r. Expressed in Arc.	w_0. Mean weight of one Observation.	ρ. Probable Error of Beginning and End.	n. Number of Meteors.	Radiant. R.A. 45°+.	Decl. 57°+.
Denning	10, 1877	8·41	±4°·82	7·9	±0°·68	24	−3°·74±0°·94	+0°·74±0°·54
"	10, 1878	7·61	4·36	6·3	0·62	20	+0·70±1·20	−0·63±0·49
"	9, 1880	6·63	3·80	5·9	0·54	13	+2·12±1·25	+0·61±0·57
"	9, 1893	2·58	1·48	5·0	0·21	16	−1·96±0·47	−0·21±0·23
"	10, 1896	4·40	2·52	5·3	0·36	29	+0·06±0·53	+0·52±0·29
"	11, 1898	2·72	1·56	5·7	0·22	32	+0·16±0·26	+1·15±0·20
"	10, 1899	2·18	1·25	7·2	0·21	15	−1·28±0·29	−0·34±0·18
Morine	9, 1893	6·38	3·66	5·2	0·51	23	−5·08±0·74	−1·30±0·72
"	11, 1893	3·70	2·12	5·4	0·29	26	+2·60±0·44	+1·22±0·29
Maggi	10, 1872	19·96	11·44	15·8	1·62	46	+0·45±0·96	+0·90±0·78
Scharbe	9, 1898	5·31	3·04	2·1	0·43	17	+4·01±1·52	+2·26±0·80
"	11, 1898	5·24	3·00	2·2	0·42	26	−2·22±1·28	+1·78±0·48
Lewitzky	9, 1898	7·17	4·11	8·7	0·57	11	−3·63±0·97	−0·38±0·83
"	11, 1898	8·36	4·79	6·4	0·67	12	−3·85±1·32	+0·64±1·00

The fourth column gives the value of the probable error of p in arc of great circle; if a small circle is drawn round the radiant with this value of r as radius, the prolongation of a meteor's path backwards to the radiant would be just as likely to pass without this circle as within, if the observation were of weight unity. If this is divided by the square root of w_o, we get the mean radius of this circle for each observer. It will be noticed that the mean weight of one of Maggi's observations is more than twice that of any of the other observers; the reason is that the former registers his meteor paths as much longer than most observers. But in spite of their great weight his observations have rather a large probable error, which may be accounted for by his having been influenced by the position of stars near to the meteor's path, for most of his meteors begin and end at a star. Of the 46 meteors observed by him, there are only 29 distinct paths; in one case 6 meteors are recorded as pursuing identically the same path. At the time of making these observations Maggi was a practised observer, having recorded paths for several years previously. Morine had observed at Poulkova for two or three years before; but I do not know how far back Lewitzky and Scharbe's observations extend. Mr. Denning seems to have become more skilled with practice, and his probable error is now very small.

But it must be remembered that there is mixed up with the probable error here found a possible real diffuseness of the radiant, and it is therefore desirable to discuss observations of other showers; but it is not easy to find a large enough number of meteor-paths all observed on *one* night to give a reliable probable error. However, these observations of Mr. Denning's seem to bear out his belief that radiant areas as such do not really exist (*Monthly Notices*, vol. xlv. p. 96), or at any rate that the radiant area is very small, which is what one would rather expect.

That the large difference between Morine's probable error on August 9 and 11 of the same year is possibly due to real differences of radiant is confirmed by the observation of another Poulkova observer, Stratonof; a chart of the meteors shows it at once. Mr. Denning's observations on the first of these nights do not confirm the Poulkova observers, his probable error being very small.

If, then, the radiant of the *Perseids* has a very small area of diffuseness, these observations show that a first-class observer is as likely as not to be in error by a quarter of a degree in recording the beginning or end of a meteor's path, whilst an observer of less extensive experience may err by half a degree. The resulting radiants will have probable errors of rather less than a quarter of a degree and of nearly three-quarters respectively.

In the opinion of Mr. Denning, three meteors will often give as good and certain a radiant as 30, especially when they are well-observed paths from a radiant of low altitude. Let us suppose then that we have 4 *Perseids* each of weight 6 and one in each quadrant and that they are inclined at 45° to the rectangular

axes, so that x and y are equally well determined. They furnish the following equations :—

$$\begin{array}{rl} \cdot 71x+\cdot 71y-p_1=0. & \text{Wt. } 6. \\ \cdot 71x-\cdot 71y-p_2=0. & 6. \\ -\cdot 71x+\cdot 71y-p_3=0. & 6. \\ -\cdot 71x-\cdot 71y-p_4=0. & 6. \end{array}$$

Whence the weights of x and y are both 12 ; if we take the probable error, r, of one observation of weight unity as $\pm 6\cdot 0$ we have

$$r_x=\frac{r}{\sqrt{p_x}}=\pm 1\cdot 73 \qquad r_y=\frac{r}{\sqrt{p_y}}=\pm 1\cdot 73$$

and therefore the probable error of the deduced radiant is

$\pm 1^\circ\cdot 8$ in R.A. and $\pm 1^\circ\cdot 0$ in Declination.

A first-class observer might have $r=\pm 2\cdot 5$, in which case the probable errors would be

$\pm 0^\circ\cdot 8$ in R.A. and $\pm 0^\circ\cdot 4$ in Declination.

But it will only be very rarely that four meteors can be observed as conveniently situated as those four ideal ones, and thus one coordinate is sure to be more strongly determined than the other. And, again, if the radiant is a point and the observer's r is known from previous observation, the more meteors that are made use of the greater will be the weight of x and y and the smaller the resulting probable error of the radiant. It seems, then, that to get a reliable determination of a radiant, as many meteors as possible should be observed and used in the reduction of their radiant point.

I have not yet been able to reduce the observations made on other days than August 9, 10, and 11, in order to discuss the motion of the radiant. The mean position of the radiants of all the observers on those three days are :—

	R.A.	Declination.	Longitude.	Latitude.
Aug. 9	$42^\circ.77 \pm 0^\circ.34$	$+56^\circ.94 \pm 0^\circ.19$	$59^\circ.25 \pm 0^\circ.24$	$38^\circ.42 \pm 3^\circ.19$
10	44.01 ± 0.23	$+56.94 \pm 0.14$	60.05 ± 0.16	38.15 ± 0.14
11	45.58 ± 0.22	$+58.22 \pm 0.15$	61.67 ± 0.15	39.07 ± 0.15

Summary of Results.

1. In deducing the radiant point, attention ought to be paid to the weights of the individual meteors.

2. An expression is therefore found, in a form capable of practical application, for assigning the proper weights.

3. It seems reasonable to assume that all meteors belonging to the same shower have nearly the same *real* length of path; the apparent length varies with the distance from the radiant. Since then an inordinately great or small weight—about 5 times or $\frac{1}{5}$ the mean weight for a given observer—indicates that the path of the meteor is not of a length proportionate to its distance from the radiant, it follows that the weights are to a certain extent a criterion of a meteor's right to be included in the determination of the radiant. But Mr. Denning's words, "radiant points should be determined by the observer of the meteors," must be remembered; the calculator must only include meteors which the observer gives him labelled as *Perseids*.

4. The effect of zenith attraction, rotation, and orbital motion of the Earth on one night's observations may be neglected as insensible in the case of the *Perseids*.

5. Assuming the radiant of this shower to be a point—

A. The probable error of a recorded beginning or end of a meteor's path varies so far as direction of path is concerned from $\pm 0^\circ{\cdot}2$ to $\pm 1^\circ{\cdot}6$.

B. To get a reliable determination of the radiant the more meteors made use of the better.

C. The probable error of a radiant derived from about 20 to 30 meteors varies from $\pm 0^\circ{\cdot}2$ to $\pm 1^\circ{\cdot}0$.

6. Assuming the radiant to be an area—

A. There are indications of a change in size of this area.

7. A discussion of observations of meteors belonging to other strong showers would decide the question of how much of the probable error here found is due to error of observation, and how much to real diffuseness of radiant.

8. The position of a radiant point derived from Mr. Denning's observations may be relied upon to within three-quarters of a degree of great circle, and I think that the present discussion, so far as it goes, makes it clear that eye-observations are of sufficient accuracy to show the existence of stationary radiants. Very great care must be taken in combining meteors to form a radiant, and if there is any doubt as to the reality of stationary radiants it is on this point, and not on the accuracy of the record of path, that it rests.

Leonids observed at Cambridge Observatory, 1900 *November* 13, 14, 15. By J. C. W. Herschel, B.A.

(*Communicated by Sir Robert Ball.*)

[The arrangement for observing the *Leonids* in 1900 was entrusted to Mr. J. C. W. Herschel, Research Student at the Observatory. He was assisted by the following members of the

University, to whom our obligations are due: Messrs. A. G. Whitehouse, B.A., Queens' College, L. N. G. Filon, King's College, J. A. Hubback, King's College, P. M. Marples, B.A., Jesus College, H. D. Wakely, St. John's College, and H. A. Webb, Trinity College.—ROBERT S. BALL.]

There were two objects in view: to keep a continuous count of all meteors seen per quarter hour; to record as many of these as were sufficiently well observed. The latter object practically covered the former. The track of a meteor was marked down *at once* on a blue map with needle-hole stars illuminated from behind, as described by Mr. Hinks in his paper on the Leonids of 1899 (*Monthly Notices*, April 1900). It is to the use of these maps that I attribute the compactness of the radiant areas, for the tracks are recorded in the most concise manner—a single line—in the form and place in which they are required and used throughout. Errors of intermediate steps are avoided, such as plotting down from notes.

Schiaparelli's geometrical method of combining tracks for the deduction of radiant points was used.

In the following table the second line includes those only "seen" but not "plotted"; the Leonids in the third line have already been counted under "plotted," and although a small number of those only "seen" were noted as "probably Leonids," they may be treated as a whole as belonging to other radiants.

Nov. 13. Period from	13^h	½	14^h	¼	½	¾	15^h	¼	½	¾	16^h	¼	½	¾	17^h	¼	½	¾	Total.
Plotted.	1	4	2	4	1	1	3	2	1	1	3	4	4	3	6	4	2	...	46
Seen.	1	4	...	...	...	...	...	1	1	...	2	2	4	1	4	...	4	...	24
Leonids.	1	2	1	2	...	...	1	1	...	...*	1	3	...	1	4	...	...	...	17

* Cloudy 10 minutes. Hazy all night with light clouds scattered about.

Nov. 14. Period from	$12\frac{1}{2}^h$	¾	13^h	¼	½	¾	14^h	¼	½	¾	15^h	Total
Plotted.	2	2	6	10	5	3	1	...	4	...	2	35
Seen.	...	5	5	6	7	4	...	1	...	...	...	28
Leonids.	...	...	2	3	1	...	1	...	2	...	...	9

After 14^h clouds, getting gradually thicker.

Nov. 15 Period from	$11\frac{1}{4}^h$	½	¾	12^h	¼	½	¾	13^h	¼	½	¾	14^h	¼	½	¾	15^h	Total.
Plotted.	2	4	4	6	3	3	3	4	4	3	5	...	5	3	1	1	51
Seen.	2	3	...	2	4	3	2	6	4	3	2	4	1	1	...	...	37
Leonids.	1	2	...	1	...	2	2	3	4	1	1	...	2	1	1	1	22

Misty till 11^h, clear till 15^h, afterwards thick clouds.

These figures show that the display of Leonids was very weak this year, with a slight access of strength on the 14th between $13\frac{1}{4}^h$ and $13\frac{1}{2}^h$, and a maximum on the 15th at about 13^h. It has been pointed out to me by Professor A. S. Herschel that the activity of neighbouring showers in several instances seems to fluctuate in sympathy with the chief shower. These numbers confirm this.

Now as to the radiant points deduced.

All the meteors which were plotted as coming from within and close round about the Sickle were considered *Leonids*, and only these, 48 in number, are here discussed. They were in general green with broad green streaks, though some were noted as "reddish," "yellow" or "bluish."

On the 13*th* 46 meteors were plotted, of which 17 were Leonids.

9 meteors definitely showed the radiants I. and VI.

7 ,, supported the radiants II., III., IV., V.

1 meteor was not assigned.

This last meteor was an outlying one, and though its line passed only 2° outside radiant I., to take count of it would much weaken the very definite determination of this radiant point, as will be seen below. (See table, columns 5 and 6.)

The determination of radiant V. is illustrative. The above seven meteors formed a somewhat loose radiant area at about $151° + 29°$; but when combined with the other two nights' observations, it turned out that the support of five of them was illusory—at least they fitted other radiants better. The two that remained crossed each other a little way below the mean centre of the seven, and fortunately three meteors were seen on the 15th which admirably supported the lowered position, and led me to re-assign one of the five to this radiant.

Radiants I. and VI. were active only on this night.

On the 14*th* 35 meteors were plotted, of which 9 were Leonids.

7 meteors definitely showed radiants II. and IV.

2 ,, supported radiants III. and VI.

On the 15*th* 51 meteors were plotted, of which 22 were Leonids.

19 meteors definitely showed the radiants II., III., IV., VII.

3 ,, supported radiant V. of the 13th.

Radiant VII. was active only on this night.

The following table sums up the results.

No.	Name.	Rad. Point. α	δ	Number of ↓'s. 13th	14th	15th	Total.	Mean deviation.	Diam. of includg. circle.	Nearest Radiants in Denning's Catalogue.
		°	°					°	°	
I.	ξ Leonids	141·8	+17·3	4	0	0	4	0·7	1·1	CIX. 4.
II.	μ Leonids	143·4	+25·3	2	3	4	9	0·8	1·5	CVIII. 6; CXV. 18, 19.
III.		147·5	+22·4	1	1	4	6	0·5	2·3	CXV. 5, 6, 12, 97 *et al.*
IV.	Great	150·5	+15·5	1	4	6	11	0·8	4·0	CXV. 56, 100.
V.	Leonid	151·9	+27·8	3	0	3	6	0·5	1·8	CXV. 68, 71.
VI.	Shower	153·0	+20·3	5	1	0	6	0·6	2·4	CXV. 80, 102, 103 *et al.*
VII.	α Leonids	156·6	+18·7	0	0	5	5	0·2	0·8	CXV. 21, 61; CXX. 7.
	Unassigned			1	0	0	1	2° from radiant I.		
				17	9	22	48			

Columns 6 and 7 give a measure of the reliability of the observations. Were all these meteors plotted on one map their lines of direction would cross each other over the whole Sickle, and it would not be very unreasonable to treat them as rough observations, and find an average central point for the whole lot. But they are worth more trouble. Closer study has shown that these 48 meteors, *which are all the Leonids that were plotted*, belong to the seven distinct and definite radiant points enumerated above. With three exceptions (both about 2°) the direction of every meteor passes within $1\frac{1}{2}$° of one of these radiant points; only 6 exceed the degree; and the average deviation is only about $\frac{2}{3}$°. The tracks have not been altered in any way, and no theoretical corrections have been applied. This result is more defined than could have been expected.

I wish to draw attention to the concordance in place of radiants III., IV. and VI. with the radiants CXV., 97, 100, 102 in Mr. Denning's Catalogue, recorded there as having been noted, by Professor Brackett's observing party at Claremont, California, on 1898 November 12, 15, and 17, at $147\frac{1}{2}+22$, $150+17\frac{1}{2}$, $152\frac{1}{2}+22$. Such a concordance has, I think, additional weight because the three radiants were in each case noted as distinct by a single party of observers; the corroboration is not merely one found by selecting single places noted independently of each other by different observers with sensible variation of position.

On a Method of Reducing Occultations of Stars by the Moon; together with the Reduction of Occultations observed on Three Occasions at the Liverpool Observatory. By H. C. Plummer, M.A.

The present paper is the result of an undertaking to reduce three series of observations of occultations and to render them available for the discussion of the Moon's semi-diameter. As I was not acquainted with a method which did not seem to leave something to be desired in point of clearness or convenience, I adopted one which offers certain considerable advantages. This method seems to differ essentially from those which have been previously employed, and it therefore appears desirable to describe it in some detail. The first object of the theory is to obtain a quite general equation expressing the geometrical conditions, on the assumption that the figure of the Moon is a sphere and that the line joining the observer to the star is a tangent line to the Moon at the time of the observation.

Let (x, y, z) be the position of the observer; (X, Y, Z) of the centre of the Moon; and (l, m, n) direction cosines of the star, referred to rectangular geocentric axes. Let R be the radius of the Moon. Then

$$\frac{\xi-x}{l}=\frac{\eta-y}{m}=\frac{\zeta-z}{n}$$

$$\frac{\xi-x}{X-x}=\frac{\eta-y}{Y-y}=\frac{\zeta-z}{Z-z}$$

represent the lines joining the observer to the star and to the centre of the Moon respectively. If, now, ψ is the angle between these lines,

$$l(X-x)+m(Y-y)+n(Z-z) \\ =\cos\psi \,.\, \sqrt{\{(X-x)^2+(Y-y)^2+(Z-z)^2\}}\ ;$$

$$R=\sin\psi \,.\, \sqrt{\{(X-x)^2+(Y-y)^2+(Z-z)^2\}}\ ;$$

$$\therefore \{l(X-x)+m(Y-y)+n(Z-z)\}^2+R^2 \\ =(X-x)^2+(Y-y)^2+(Z-z)^2.$$

Now let ρ be the Earth's radius and ϕ the geocentric latitude at the place of observation; T, the sidereal time (or R.A. of the zenith); A, D, the apparent R.A. and declination of the star; α, δ, the geocentric R.A. and declination of the Moon. Also let r, P, s be the Moon's radius vector, parallax, and semi-diameter respectively. Then, if the axis of x has been taken through the First Point of Aries and the axis of z through the Pole,

$$X=r\cos\delta\cos\alpha\ ;\ Y=r\cos\delta\sin\alpha\ ;\ Z=r\sin\delta\ ;$$

$$l=\cos D\cos A\ ;\ m=\cos D\sin A\ ;\ n=\sin D\ ;$$

$$x=\rho\cos\phi\cos T\ ;\ y=\rho\cos\phi\sin T\ ;\ z=\rho\sin\phi.$$

Making these substitutions in the above equation, we obtain

$$R^2+\{r[\cos\delta\cos D\cos(A-a)+\sin D\sin\delta]$$
$$-\rho[\cos D\cos\phi\cos(A-T)+\sin D\sin\phi]\}^2$$
$$=r^2+\rho^2-2r\rho\{\cos\delta\cos\phi\cos(a-T)+\sin\delta\sin\phi\}.$$

Now

$$\cos\delta\cos D\cos(A-a)+\sin D\sin\delta=\cos\Delta \quad \ldots \quad (1)$$

$$\cos D\cos\phi\cos(A-T)+\sin D\sin\phi=\cos Z \quad \ldots \quad (2)$$

$$\cos\delta\cos\phi\cos(a-T)+\sin\delta\sin-\phi=\cos Z' \quad \ldots \quad (3)$$

where Δ is the geocentric distance of the star from the Moon's centre, Z is the true Z.D. of the star and Z' is the true Z.D. of the Moon's centre. Hence

$$R^2+(r\cos\Delta-\rho\cos Z)^2=r^2+\rho^2-2r\rho\cos Z'$$

or

$$R^2=r^2\sin^2\Delta+\rho^2\sin^2 Z-2r\rho(\cos Z'-\cos\Delta\cos Z).$$

But $r\sin P=1$; $r\sin s=R$; the Earth's equatorial radius being unity.

Therefore

$$\sin^2 s=\sin^2\Delta+\rho^2\sin^2 P\sin^2 Z-2\rho\sin P(\cos Z'-\cos\Delta\cos Z) \quad (4)$$

and this is the geometrical equation sought.

We are now in a position to derive the equations of condition. Since ρ and P do not occur independently in the fundamental equation, p may be written for $\rho\sin P$. Also put S equal to $\sin^2 s$, and let

$$C=\cos Z'-\cos\Delta\cos Z \quad \ldots \quad \ldots \quad \ldots \quad (5)$$

$$\Sigma=\sin^2\Delta+p^2\sin^2 Z-2pC \quad \ldots \quad \ldots \quad (6)$$

Then, if the observed and tabular quantities involved were quite accurate, the equation $S=\Sigma$ would be satisfied exactly. Actually, however, the quantities s, p, a, δ, A, D, and t, the mean time of the observation, require corrections ds, dp, da, $d\delta$, dA, dD, and dt. Substituting $s+ds$ for s, &c., an equation is obtained of the form:

$$\Sigma-S=\sin 2s\,.\,ds-Bdp-Eda-E'dA-Fd\delta-F'dD-Hdt \quad (7)$$

wherein

$$E=\frac{\partial\Sigma}{\partial a};\ F=\frac{\partial\Sigma}{\partial\delta};\ E'=\frac{\partial\Sigma}{\partial A};\ F'=\frac{\partial\Sigma}{\partial D};$$

$$H=\frac{d\Sigma}{dt}=\frac{\partial\Sigma}{\partial T}\cdot\frac{dT}{dt}+\frac{\partial\Sigma}{\partial a}\cdot\frac{da}{dt}+\frac{\partial\Sigma}{\partial\delta}\cdot\frac{d\delta}{dt}$$

$$=G+E\frac{da}{dt}+F\frac{d\delta}{dt} \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (8)$$

and

$$B = \frac{\partial \Sigma}{\partial p} = 2(p \sin^2 Z - C) \quad \dots \quad \dots \quad \dots \quad \dots \quad \dots \quad (9)$$

Hence

$$E = -2 \cos \Delta \frac{\partial}{\partial a} (\cos \Delta) - 2p \left\{ \frac{\partial}{\partial a} (\cos Z') - \cos Z \frac{\partial}{\partial a} (\cos \Delta) \right\}$$

$$= -2 \{(\cos \Delta - p \cos Z) \cos \delta \cos D \sin (A - a) \\ - p \cos \delta \cos \phi \sin (a - T)\} \dots (10)$$

$$F = -2 \cos \Delta \frac{\partial}{\partial \delta} (\cos \Delta) - 2p \left\{ \frac{\partial}{\partial \delta} (\cos Z') - \cos Z \frac{\partial}{\partial \delta} (\cos \Delta) \right\}$$

$$= -2 \{(\cos \Delta - p \cos Z)[-\sin \delta \cos D \cos (A - a) + \sin D \cos \delta] \\ + p[-\sin \delta \cos \phi \cos (a - T) + \cos \delta \sin \phi]\} \dots (11)$$

and

$$G = \frac{\partial \Sigma}{\partial T} \cdot \frac{dT}{dt} = \frac{dT}{dt} \cdot \left\{ -2p^2 \cos Z \frac{\partial}{\partial T} (\cos Z) \right.$$

$$\left. - 2p \left[\frac{\partial}{\partial T} (\cos Z') - \cos \Delta \frac{\partial}{\partial T} (\cos Z) \right] \right\}$$

$$= -2p \frac{dT}{dt} \{(p \cos Z - \cos \Delta) \cos D \cos \varphi \sin (A - T) \\ + \cos \delta \cos \phi \sin (a - T)\} \quad \dots \quad (12)$$

Finally,

$$E' = -2 \cos \Delta \frac{\partial}{\partial A} (\cos \Delta) + 2p \left\{ \cos \Delta \frac{\partial}{\partial A} (\cos Z) \right.$$

$$\left. + \cos Z \frac{\partial}{\partial A} (\cos \Delta) \right\}$$

$$= 2 \{(\cos \Delta - p \cos Z) \cos \delta \cos D \sin (A - a) \\ - p \cos \Delta \cos D \cos \phi \sin (A - T)\} \dots (13)$$

and

$$F' = -2 \cos \Delta \frac{\partial}{\partial D} (\cos \Delta) + 2p \left\{ \cos \Delta \frac{\partial}{\partial D} (\cos Z) \right.$$

$$\left. + \cos Z \frac{\partial}{\partial D} (\cos \Delta) \right\}$$

$$= 2 \{(\cos \Delta - p \cos Z)[\cos \delta \sin D \cos (A - a) - \cos D \sin \delta] \\ + p \cos \Delta[-\sin D \cos \phi \cos (A - T) + \cos D \sin \phi]\} \dots (14)$$

We thus have the means of calculating accurately all the coefficients of the equation of condition. It is only necessary to add, since p is not itself a tabular quantity, that

$$dp = \rho \cos P \cdot dP + \sin P \cdot d\rho \quad \dots \quad \dots \quad (15)$$

It is now necessary to reconsider the above formulæ from the point of view of the computer. In the first place cos Z and cos Z′ can be found by means of (2) and (3). It is assumed that 7-figure logarithms are used, and it may be pointed out that perfect accuracy will be attained if the terms of Σ, none of which in fact exceeds ·0005, are calculated to ten places of decimals. Equation (1) is unsuitable for obtaining $\sin^2 \Delta$, but from it can be derived

$$\begin{aligned}\sin^2\Delta &= 1-\cos^2\Delta = 1-\{\cos(D-\delta)-2\cos\delta\cos D\sin^2\tfrac{1}{2}(A-\alpha)\}^2\\ &= \sin^2(\delta-D)+4\cos\delta\cos D\cos(\delta-D)\sin^2\tfrac{1}{2}(A-\alpha)\\ &\qquad -4\cos^2\delta\cos^2 D\sin^4\tfrac{1}{2}(A-\alpha)\\ &= \sin^2(\delta-D)+\cos D\cos\delta\cos(\delta-D)\sin^2(A-\alpha)\\ &\qquad +\sin 2D\sin 2\delta\sin^4\tfrac{1}{2}(A-\alpha)\quad \dots\quad \dots\quad \dots\quad (16)\end{aligned}$$

In this form the last term is generally negligible, but in any case it is easily added as a small correction; its importance depends only on the fact that it is always positive. From $\sin^2 \Delta$ can be deduced $\cos \Delta$, and then we have C from (5). This is the most convenient way of calculating C, but it must be said that the resulting value of $2p$C cannot be trustworthy beyond nine places, since C is known only to seven places of decimals. This falls short of the highest standard of accuracy, but I have generally contented myself with this method: partly because of its convenience, partly because the error introduced is an *accidental* one, small in comparison with those which depend on the star's place and the observed time, and partly because other methods failed to reveal errors in the simpler process, carefully performed, such as seemed to necessitate or warrant the extra labour involved by their adoption. Two alternatives may, however, be mentioned here. The angles Z and Z′ are known from their cosines. Then (5) may be written

$$C=2\sin\tfrac{1}{2}(Z+Z')\sin\tfrac{1}{2}(Z-Z')+2\cos Z\sin^2\tfrac{1}{2}\Delta \quad \dots\quad (17)$$

Or referring to the *geocentric* spherical triangle formed by the zenith (Z), the Moon's centre (M) and the star (S), it is seen that

$$C=\cos Z'-\cos\Delta\cos Z=\sin\Delta\sin Z\cos ZSM.$$

But if P is the pole, ZSM = PSM + ZSP = $\varpi+\zeta$, say.

$$\left.\begin{aligned}\therefore\ C&=\sin\Delta\sin Z\cos(\varpi+\zeta)\\ \text{where }\sin\varpi&=\cos\delta\sin(A-\alpha)\,/\,\sin\Delta\\ \sin\zeta&=\cos\phi\sin(T-A)\,/\,\sin Z\end{aligned}\right\}\dots\quad\dots\quad(18)$$

These latter equations may not give the auxiliary angles without ambiguity: in that case reference to a figure will remove the difficulty. The use of equations (18) involves considerable extra labour, but they possess the advantage that a comparison of the

value of C so obtained with the value obtained directly from (5) furnishes a very complete if not a very accurate check on the work. There is no further difficulty in finding $\Sigma - S$, which is at present expressed in circular measure.

In finding the coefficients of equation (7) 5-figure logarithms are of course amply sufficient. In my own computations, B has been found from equation (9). In finding E, F and G the following slightly modified approximate formulæ have been used :—

$$E = -2 \cos \delta \{(1 - p \cos Z) \cos D \sin (A - \alpha) \\ - p \cos \phi \sin (\alpha - T)\} \quad \dots \quad (19)$$

$$F = -2 \{(1 - p \cos Z) \sin (D - \delta) + p[\sin \phi \cos \delta \\ - \sin \delta \cos \phi \cos (T - \alpha)]\} \quad \dots \quad (20)$$

$$G = \quad 2p \frac{dT}{dt} \cos \phi \cos D \{\sin (A - \alpha) \cos (A - T) \\ - p \cos Z \sin (A - T)\} \quad \dots \quad (21)$$

In equation (8) $\frac{d\alpha}{dt}$ and $\frac{d\delta}{dt}$ are most easily expressed in seconds of arc per second of mean time; for the sake of uniformity therefore we take $\log\left(2 \frac{dT}{dt}\right) = 1{\cdot}47831$. It is easy to see, either by comparing equations (10) and (13), and (11) and (14), or from general considerations, that $E' = -E$ and $F' = -F$ approximately. In consequence of this it has not been thought worth while to calculate the coefficients E′ and F′ separately. In fact these coefficients are not needed with great accuracy, for if considerable values be assigned to dA and dD, terms of the second order will become necessary in equation (7). The term in $d\rho$ is most convenient if we are dealing with observations made at a single observatory. If we have to combine observations made at different observatories, it will be necessary to remove the term in $d\rho$ in equation (15) and to use $-B\rho \cos P$ (which differs little from $-B$) as the coefficient of a term in dP on the right-hand side of equation (7). If it is desired to improve ρ by adding $d\rho$, the quantity $B \sin P\, d\rho$ must be added to the left-hand side of the same equation. For an increase of altitude of 209 feet, $d\rho = {\cdot}00001$, while $B \sin P$ is not likely to exceed ·0001. In the final equation we divide $\Sigma - S$ by $\sin 1''$ in order to transform the residual from circular measure into seconds of arc, and divide the whole equation by $\sin 2s$ so as to make the coefficient of ds unity.

It is well known that refraction exercises an effect, which is of a parallactic nature, on the circumstances of an occultation. If there were no terrestrial atmosphere it would be necessary for the observer to change his position in order to see the occultation at the same time that he makes his observation under actual conditions. The effect, which is generally evanescent and always small, is presumably neglected in the Greenwich reductions, since

no reference is made to it, but it is taken into account by those who follow Bessel, as for instance by Küstner in his admirable memoir on "Nine Occultations of the *Pleiades*" It is easy to see that the effect is allowed for, if the radius ρ is increased by an amount x such that

$$1+x=\mu \sin z/\sin Z$$

where μ is the refractive index of the air at the surface of the Earth, and z is the apparent Z.D. of the star (*cf. Chauvenet's Astronomy*, 5th ed., vol. i., p. 516). Now $z=Z-a \tan Z$ where $a \tan Z$ is small. Consequently

$$1+x=\mu(\sin Z-a \sin Z)/\sin Z=\mu(1-a)$$

or

$$x=\mu-1-\mu a=\mu-1-a.$$

It is quite clear that an accurate calculation of this quantity can be made only if μ and a are known with great exactness. If we adopt Gladstone and Dale's law as to the dependence of the refractive index on pressure, and Mascart's numbers (*Comptes Rendus*, t. lxxviii., p. 617) for the index itself and the temperature coefficient, we have

$$\mu-1=\cdot0002923(1-\cdot00383t)\frac{p}{p_0}.$$

And using Bessel's formula and numbers for the refraction we have

$$a=\alpha\beta^A\gamma^\lambda=\alpha\left(\frac{p}{p_0}\right)^{1+m}(1-\epsilon t)^{1+n}$$

where m and n are small, and $\epsilon=\cdot00364$. At the zenith, when $t=0°$C and $p=760$ mm., $\alpha=\cdot0002927$, we may put then $a=\cdot0002927-a'$ for any Z.D., and let $p/p_0=1+q$. If we make these transformations in the expression for x, we obtain a formula which is certainly erroneous in a slight degree, inasmuch as it gives a negative value of x at the zenith when $q=t=0$. This may be due to the fact that Bessel's temperature coefficient ·00364 is too small. However it is only necessary to retain terms amounting to ·000001, and from an examination in detail it is concluded that we may take $x=a'(1+q-\cdot00364t)$, and that no serious error will be introduced by assuming, as has been generally done, a mean state of the atmosphere, in which case we find the following :—

Z=	0°	50°	60°	65°	70°	75°	80°	85°
x=	·000 000	000	001	002	003	005	012	038

It is to be feared that the constants of refraction may be insufficiently exact in the only case where they are of importance here, *i.e.* at great zenith distances. For this reason the correction has not been applied in the reductions which follow, but its

magnitude in the few instances in which it amounts to $0''\cdot01$ may be recorded here, though, as a matter of fact, in no case has it any importance. In the final equations the coefficient of $dp = -B/\sin 2s = B'$ say, and the residual is $(\Sigma - S)/\sin 2s \sin 1''$. It is only necessary then to add $B \sin P \,.\, x/\sin 2s \sin 1'' = -B'Px$, where P is expressed in seconds, to correct the final equation for the effect of refraction. The equations affected are confined to Series I, and the corrections are $-0''\cdot02$ in No. 3, $-0''\cdot01$ in Nos. 5, 6, 7, and 9, and $+0''\cdot01$ in No. 11.

The accompanying reductions refer to observations made by the Director of the Liverpool Observatory on the following dates :—

1897 July 23	(*Monthly Notices*,	vol. lviii.,	p.	20)
1898 Dec. 27	(„	„ lix.,	p.	165)
1899 Dec. 16	(„	„ lx.,	p.	222)

On the first of these dates the *Pleiades* were occulted, and on the other two the Moon was eclipsed. A few corrections have been made in the designations of the stars, and in several instances it has not been found possible to identify the stars occulted. In Series I the mean places of the stars have been taken from Elkin's memoir on the *Pleiades*, except in those cases where the apparent places were given in the *Nautical Almanac* of the year. In columns 5 and 6 are to be found apparent coordinates (A and D) as used in the reduction. The stars in Series II are all taken directly from a list prepared by the photographic method at the Poulkova Observatory (*Astr. Nachr.*, No. 3533). For Series III the three stars B.D. + 22°, Nos. 999, 1004 and 1006, were taken from the *Astr. Ges.* Catalogue (Berlin). The coordinates of No. 1011 are the result of my own reduction of a plate taken at the University Observatory, Oxford, by Mr. Bellamy, to whom, as well as to Professor Turner, I am indebted for kind assistance in this connection. The corrections deduced from the plate to the Berlin meridian places are these :—

B.D. + 22°, 999	$\Delta A = -0^s\cdot05$	$\Delta D = -0''\cdot4$
1004	$+0\cdot02$	$-0\cdot2$
1006	$+0\cdot02$	$+0\cdot2$

As regards the places of the Moon (α and δ), columns 7 and 8 contain the values deduced by interpolation from the *Nautical Almanac* with the following assumed corrections added :—

1897 July 23	$\Delta\alpha = +0^s\cdot06$	$\Delta\delta = -2''\cdot0$
1898 Dec. 27	$+0\cdot20$	$+2\cdot3$
1899 Dec. 16	$+0\cdot38$	$+0\cdot8$

These are based on observations made at Greenwich, in the third case directly, and in the two former by estimation, not very reliable probably, from the results of previous and subsequent nights. The unpublished results were kindly communicated to me by the Astronomer Royal. The assumed position of the observatory is that given in the *Nautical Almanac*, and no correction has been made for the altitude, which is about ·000011 in units of the Earth's radius. The omission contributes to the term dp, and might be allowed for in the way already explained. But this is unnecessary if the term is eliminated from the final equations, and if this is done the result will be independent of the assumed figure of the Earth.

I. Occultation of the Pleiades, 1897 July 23.

Reference No.	Name of Star.	Phase.	Sidereal Time.	Star's R.A.	Star's Decl.	Moon's R.A.	Moon's Decl.	Moon's Parallax.	Moon's Semi-diameter.
			h m s	h m s	° ′ ″	h m s	° ′ ″	′ ″	′ ″
1	Electra	D.	20 17 23.16	3 38 47.72	23 47 32.1	3 35 41.67	24 22 54.3	54 11.72	14 47.53
2	8	,,	20 52 17.98	3 40 8.60	23 52 38.45	3 36 55.60	24 26 22.0	54 11.82	14 47.56
3	Merope	,,	20 52 56.59	3 40 14.96	23 37 48.3	3 36 56.96	24 26 25.8	54 11.82	14 47.56
4	10	,,	21 1 50.90	3 40 21.90	23 56 14.3	3 37 15.83	24 27 18.4	54 11.84	14 47.57
5	18	,,	21 16 45.59	3 41 14.14	23 49 23.5	3 37 47.43	24 28 46.2	54 11.88	14 47.58
6	*p*	,,	21 17 31.11	3 41 15.21	23 48 3.3	3 37 49.04	24 28 50.7	54 11.89	14 47.58
7	Alcyone	,,	21 21 28.16	3 41 23.92	23 47 22.1	3 37 57.42	24 29 13.8	54 11.90	14 47.58
8	29	,,	21 54 28.77	3 42 24.22	24 1 55.0	3 39 7.43	24 32 26.6	54 11.99	14 47.60
9	Pleione	,,	22 13 9.53	3 43 5.70	23 49 29.1	3 39 47.08	24 34 14.5	54 12.05	14 47.62
10	32	,,	22 17 48.19	3 43 15.64	24 4 9.4	3 39 56.94	24 34 41.3	54 12.07	14 47.63
11	9	R.	21 47 45.87	3 40 10.84	23 52 18.45	3 38 53.18	24 31 47.4	54 11.97	14 47.60
12	Alcyone	,,	22 15 46.66	3 41 23.92	23 47 22.1	3 39 52.64	24 34 29.6	54 12.06	14 47.62

II. Occultations during the Lunar Eclipse, 1898 December 27.

Reference No.	Name of Star.	Phase.	Sidereal Time.	Star's R.A.	Star's Decl.	Moon's R.A.	Moon's Decl.	Moon's Parallax.	Moon's Semi-diameter.
	°		h m s	h m s	° ′ ″	h m s	° ′ ″	′ ″	′ ″
1	B.D. + 23 1392	D.	4 59 30.11	6 26 53.84	23 20 35.7	6 25 38.52	23 34 28.4	54 6.78	14 46.19
2	B.D. + 23 1402	,,	5 3 32.66	6 27 42.12	23 7 57.0	6 25 47.17	23 34 12.0	54 6.76	14 46.18
3	B.D. + 23 1403	,,	5 13 6.43	6 27 57.08	23 7 29.3	6 26 7.61	23 33 33.2	54 6.70	14 46.16

Reference No.	Name of Star.	Phase.	Sidereal Time. h m s	Star's R.A. h m s	Star's Decl. ° ′ ″	Moon's R.A. h m s	Moon's Decl. ° ′ ″	Moon's Parallax. ′ ″	Moon's Semi-diameter. ′ ″
4	B.D. +22° 1385	D.	5 37 32·64	6 28 4·28	22 51 36·1	6 26 59·90	23 31 53·0	54 6·54	14 46·12
5	B.D. +23 1407	"	5 58 24·96	6 28 31·15	23 16 40·0	6 27 44·53	23 30 26·5	54 6·41	14 46·08
6	B.D. +22 1392	"	6 0 7·44	6 29 3·42	22 56 19·6	6 27 48·18	23 30 19·4	54 6·40	14 46·08
7	B.D. +23 1415	"	6 26 55·14	6 29 51·71	23 1 56·0	6 28 45·44	23 28 27·3	54 6·23	14 46·04
8	B.D. +23 1416	"	6 27 40·36	6 29 53·23	23 0 58·3	6 28 47·05	23 28 24·1	54 6·22	14 46·04
9	B.D. +22 1369	R.	5 26 21·10	6 26 27·11	22 54 31·8	6 26 35·97	23 32 39·0	54 6·61	14 46·14
10	B.D. +23 1389	"	5 39 13·62	6 26 35·70	23 11 28·6	6 27 3·50	23 31 46·1	54 6·53	14 46·12
11	B.D. +23 1407	"	6 20 9·13	6 28 31·15	23 16 40·0	6 28 30·98	23 28 55·7	54 6·27	14 46·05
12	B.D. +23 1402	"	6 23 12·12	6 27 42·12	23 7 57·0	6 28 37·50	23 28 42·9	54 6·25	14 46·04
13	B.D. +22 1385	"	6 32 30·15	6 28 4·28	22 51 36·1	6 28 57·37	23 28 3·7	54 6·19	14 46·03
14	B.D. +23 1403	"	6 32 40·18	6 27 57·08	23 7 29·3	6 28 57·73	23 28 3·0	54 6·19	14 46·03

III. Occultations during the Lunar Eclipse, 1899 December 16.

Reference No.	Name of Star.	Phase.	Sidereal Time. h m s	Star's R.A. h m s	Star's Decl. ° ′ ″	Moon's R.A. h m s	Moon's Decl. ° ′ ″	Moon's Parallax. ′ ″	Moon's Semi-diameter. ′ ″
1	B.D. +22° 1004	D.	6 27 28·95	5 37 1·77	22 37 38·0	5 36 43·27	22 56 30·5	56 11·31	15 20·18
2	B.D. +22 1006	"	6 36 36·24	5 37 9·10	22 39 8·3	5 37 4·39	22 56 15·4	56 11·11	15 20·12
3	B.D. +22 1011	"	6 44 25·03	5 37 45·09	22 30 33·2	5 37 22·47	22 56 2·3	56 10·95	15 20·08
4	B.D. +22 999	R.	6 58 22·01	5 36 12·17	22 32 54·08	5 37 54·74	22 55 38·6	56 10·64	15 19·99
5	B.D. +22 1006	"	7 18 20·79	5 37 9·10	22 39 8·3	5 38 40·95	22 55 3·9	56 10·21	15 19·88

I. *Occultation of the Pleiades*, 1897 *July* 23.

1.	$+1''.25 = ds$	$-.0241\,dp$	$+.7364\,da$	$+.5833\,d\delta$	$+.6497\,dt$
2.	$+4.17 = ds$	$+.0248\,dp$	$+.7511\,da$	$+.5680\,d\delta$	$+.6403\,dt$
3.	$+2.02 = ds$	$+.8683\,dp$	$+.8256\,da$	$-.4379\,d\delta$	$+.5811\,dt$
4.	$+2.06 = ds$	$-.1375\,dp$	$+.6379\,da$	$+.7121\,d\delta$	$+.5861\,dt$
5.	$+7.11 = ds$	$+.5206\,dp$	$+.9125\,da$	$+.1109\,d\delta$	$+.6690\,dt$
6.	$-3.33 = ds$	$+.5895\,dp$	$+.9047\,da$	$-.0007\,d\delta$	$+.6520\,dt$
7.	$-2.03 = ds$	$+.6566\,dp$	$+.9065\,da$	$-.0739\,d\delta$	$+.6439\,dt$
8.	$+5.14 = ds$	$+.1032\,dp$	$+.7607\,da$	$+.5634\,d\delta$	$+.6043\,dt$
9.	$+0.45 = ds$	$+.8544\,dp$	$+.8055\,da$	$-.4760\,d\delta$	$+.5115\,dt$
10.	$+3.65 = ds$	$+.2025\,dp$	$+.8065\,da$	$+.4623\,d\delta$	$+.5996\,dt$
11.	$-5.08 = ds$	$-.5788\,dp$	$-.9041\,da$	$-.0263\,d\delta$	$-.3391\,dt$
12.	$-4.40 = ds$	$-.0049\,dp$	$-.6912\,da$	$-.6449\,d\delta$	$-.2701\,dt$

II. *Occultations during the Lunar Eclipse*, 1898 *December* 27.

1.	$+5.63 = ds$	$-.4064\,dp$	$+.3122\,da$	$+.9433\,d\delta$	$+.0961\,dt$
2.	$+2.85 = ds$	$+.1580\,dp$	$+.9140\,da$	$+.1099\,d\delta$	$+.3881\,dt$
3.	$+2.20 = ds$	$+.1345\,dp$	$+.9130\,da$	$+.1113\,d\delta$	$+.3814\,dt$
4.	$+4.95 = ds$	$+.5078\,dp$	$+.4789\,da$	$-.8603\,d\delta$	$+.2416\,dt$
5.	$-0.80 = ds$	$-.4159\,dp$	$+.3996\,da$	$+.8985\,d\delta$	$+.1036\,dt$
6.	$+0.80 = ds$	$+.2968\,dp$	$+.8192\,da$	$-.4530\,d\delta$	$+.3574\,dt$
7.	$+1.64 = ds$	$-.0129\,dp$	$+.9181\,da$	$+.0419\,d\delta$	$+.3480\,dt$
8.	$+5.96 = ds$	$+.0157\,dp$	$+.9232\,da$	$-.0189\,d\delta$	$+.3538\,dt$
9.	$-1.21 = ds$	$+.2531\,dp$	$-.6465\,da$	$-.7074\,d\delta$	$-.4214\,dt$
10.	$-0.14 = ds$	$-.3473\,dp$	$-.8073\,da$	$+.4738\,d\delta$	$-.3222\,dt$
11.	$-2.38 = ds$	$-.4797\,dp$	$-.0493\,da$	$+.9946\,d\delta$	$-.0810\,dt$
12.	$-2.32 = ds$	$-.2240\,dp$	$-.8311\,da$	$+.4265\,d\delta$	$-.3449\,dt$
13.	$-0.52 = ds$	$+.3234\,dp$	$-.7184\,da$	$-.6216\,d\delta$	$-.2316\,dt$
14.	$+3.43 = ds$	$-.2108\,dp$	$-.8273\,da$	$+.4402\,d\delta$	$-.3478\,dt$

III. *Occultations during the Lunar Eclipse*, 1899 *December* 16.

1.	$-3.24 = ds$	$-.4330\,dp$	$+.6954\,da$	$+.6501\,d\delta$	$+.2544\,dt$
2.	$-2.77 = ds$	$-.4950\,dp$	$+.5822\,da$	$+.7711\,d\delta$	$+.1988\,dt$
3.	$-3.59 = ds$	$-.2908\,dp$	$+.8910\,da$	$+.2406\,d\delta$	$+.3431\,dt$
4.	$+0.26 = ds$	$-.0643\,dp$	$-.7082\,da$	$+.4364\,d\delta$	$-.4354\,dt$
5.	$+2.52 = ds$	$-.1817\,dp$	$-.4068\,da$	$+.8982\,d\delta$	$-.2492\,dt$

It was obvious, of course, that the above reductions were altogether insufficient in number to give by themselves any reliable value of the semi-diameter of the Moon, but an attempt was made to examine in a general manner the results which

N 2

might be deduced from the equations. The attempt was not successful, and it is not without interest to consider why this was so. The case of the ten disappearances of stars in the *Pleiades*, I. 1–10, is typical. The equations were given equal weights after division by the coefficients of dt, which term was afterwards neglected of course. The star places are known to be very accurate, and the residual, therefore, is fairly attributable to the error in the observed quantity—the time, and can be treated in accordance with the theory of least squares. Theoretically, this method seems reasonable, but it may have the result of giving an overwhelming weight to the result of an occultation at a point of elevation or depression in the Moon's figure. It would seem, then, that a compromise is desirable in some cases, but the question is one which I do not pretend to decide. As regards the equations referred to, this difficulty did not exist, and the four normal equations were at once formed in ds, dp, da and $d\delta$. It was then found that these equations were not, in any real sense, consistent and independent, as would be necessary for the determination of the four unknowns. In fact, they could be reduced to two without sacrificing any of the information which they were capable of giving. This result can be referred, I think, to two simple causes. In the first place, the observations do not extend over a long interval of time, and the Moon's change of position is small. Now in any position it is clear that if a compensating change were made in the radius of the Moon, the Moon's distance from the observer might be changed without any effect on the phenomena. Consequently the Moon's *apparent* semi-diameter and parallax cannot be determined independently from occultations observed during a short time at a single observatory. In a similar way if disappearances alone are considered, it is evident that the effect of moving the centre of the Moon along its own apparent path while changing at the same time its semi-diameter so that the advancing point of the edge retains its position, will be very small in the case of occulted stars which lie near that path. In fact, in both cases we shall be trying to determine small quantities of the second order, and it is inevitable that the results will be expressed in terms of the residual errors. The difficulty can only be overcome by combining results obtained at distant observatories, and it is in the hope that the reductions given above may be utilised in this manner that this work has been undertaken and published.

Oxford: 1901 *January* 7.

Observations of Occultations of Stars and Saturn by the Moon, made at the Royal Observatory, Greenwich, in the Year 1900.

(*Communicated by the Astronomer-Royal.*)

Day.	Phenomenon.	Telescope.	Power.	Moon's Limb.	Mean Solar Time of Observation. h m s	Observer.
1900. Jan. 9	Disapp. 27 Arietis	Sheepshanks Equat.	55	Dark	9 15 2·38	AC.
9 (*a*)	,, ,,	28-inch Equat.	670	,,	9 15 2·38	B.
Feb. 6	,, δ Arietis	,,	670	,,	8 35 20·94	B.
6	,, ,,	Sheepshanks Equat.	55	,,	8 35 20·71	WB.
6	,, ,,	Corbett Equat.	100	,,	8 35 20·34	HF.
6	,, ,,	Old Altazimuth	100	,,	8 35 21·05	S.
6	Reapp. ,,	,, ,,	100	Bright	9 25 29·35	S.
7 (*b*)	Disapp. A² Tauri	Sheepshanks Equat.	55	Dark	7 2 25·77	R.
April 4 (*c*)	,, ο Tauri	Astrographic Equat.	225	,,	9 29 18·84	H.
4	,, ,,	Sheepshanks Equat.	55	,,	9 29 19·86	R.
May 7	,, 19 Sextantis	Old Altazimuth	100	,,	10 42 2·20	S.
15	Reapp. 15 Ophiuchi	Sheepshanks Equat.	100	,,	13 58 22·55	B.
June 2	Disapp. κ Cancri	Old Altazimuth	100	,,	8 31 35·36	H.
July 11	,, ξ² Sagittarii	Sheepshanks Equat.	55	,,	12 18 44·25	AC.
11	,, ,,	Astrographic Equat.	225	,,	12 18 44·24	S.

Day. 1900.	Phenomenon.		Telescope.	Power.	Moon's Limb.	Mean Solar Time of Observation. h m s	Observer.
Sept. 3 (*d*)	Disapp.	Outer Edge of Saturn's Ring, 1st Limb	28-inch Equat.	470	Dark	7 14 59·55	L.
3	"		Sheepshanks Equat.	120	"	7 15 (9·10)	AC.
3 (*e*)	"		Corbett Equat.	100	"	7 15 2·55	B.
3	"		Astrographic Equat.	225	"	7 15 1·29	R.
3	"		Old Altazimuth	100	"	7 15 (8·54)	S.
3	"	Inner Edge of Saturn's Ring, 1st Limb	28-inch Equat.	470	"	7 15 17·21	L.
3	"		Corbett Equat.	100	"	7 15 16·01	B.
3	"		Astrographic Equat.	225	"	7 15 16·25	R.
3	"		Old Altazimuth	100	"	7 15 (21·00)	S.
3	"	Saturn's Ball, 1st Limb	28-inch Equat.	470	"	7 15 24·48	L.
3	"	" "	Sheepshanks Equat.	120	"	7 15 27·04	AC.
3	"	" "	Corbett Equat.	100	"	7 15 24·98	B.
3	"	" "	Astrographic Equat.	225	"	7 15 26·22	R.
3	"	" "	Old Altazimuth	100	"	7 15 (28·97)	S.
3	"	" 2nd Limb	28-inch Equat.	470	"	7 16 24·02	L.
3	"	" "	Sheepshanks Equat.	120	"	7 16 (19·89)	AC.
3	"	" "	Corbett Equat.	100	"	7 16 23·82	B.
3	"	" "	Astrographic Equat.	225	"	7 16 23·56	R.
3	"	" "	Old Altazimuth	100	"	7 16 (28·80)	S.

Day. 1900.	Phenomenon.		Telescope.	Power.	Moon's Limb.	Mean Solar Time of Observation. h m s	Observer.
Sept. 3	Disapp.	Inner Edge of Saturn's Ring, 2nd Limb	28-inch Equat.	470	Dark	7 16 34·60	L.
3	″		Sheepshanks Equat.	120	″	7 16 35·85	AC.
3 (e)	″		Corbett Equat.	100	″	7 16 38·78	B.
3	″		Astrographic Equat.	225	″	7 16 (44·01)	R.
3	″		Old Altazimuth	100	″	7 16 (42·76)	S.
3	″	Outer Edge of Saturn's Ring, 2nd Limb	28-inch Equat.	470	″	7 16 57·23	L.
3	″		Sheepshanks Equat.	120	″	7 16 56·79	AC.
3	″		Corbett Equat.	100	″	7 16 56·73	B.
3	″		Astrographic Equat.	225	″	7 16 57·37	R.
3	″		Old Altazimuth	100	″	7 16 57·22	S.
3 (f)	Reapp.	Inner Edge of Saturn's Ring, 1st Limb	Astrographic Equat.	120	Bright	8 10 10·39	R.
3	″	Saturn's Ball, 1st Limb	″ ″	120	″	8 10 20·36	R.
3	″	″ 2nd Limb	28-inch Equat.	470	″	8 10 47·33	L.
3	″	″ ″	Astrographic Equat.	120	″	8 10 52·27	R.
3	″	Inner Edge of Saturn's Ring, 2nd Limb	28-inch Equat.	470	″	8 10 59·79	L.
3 (f)	″		Astrographic Equat.	120	″	8 11 4·24	R.
3	″	Outer Edge of Saturn's Ring, 2nd Limb	28-inch Equat.	470	″	8 11 14·26	L.
3	″		Astrographic Equat.	120	″	8 11 16·21	R.
3	″		Old Altazimuth	100	″	8 11 16·96	S.
4	Disapp.	ξ^1 Sagittarii	28-inch Equat.	670	Dark	7 35 0·88	B.
4	″	″	Sheepshanks Equat.	120	″	7 35 0·25	HF.
4	″	″	Astrographic Equat.	225	″	7 35 0·93	S.

Day.	Phenomenon.	Telescope.	Power.	Moon's Limb.	Mean Solar Time of Observation. h m s	Observer.
1900. Sept. 4 (*e*)	Reapp. ξ^1 Sagittarii	28-inch Equat.	670	Bright	8 49 17·12	B.
4 (*g*)	" "	Sheepshanks Equat.	120	"	8 49 (27·81)	HF.
4	" "	Astrographic Equat.	225	"	8 49 15·69	S.
12	Disapp. π Arietis	" "	225	"	12 35 28·64	PM.
13	" 13 Tauri	" "	225	"	9 42 44·36	S.
13	" 14 Tauri	" "	225	"	10 14 12·30	S.
13 (*g*)	Reapp. "	" "	225	Dark	11 8 (56·47)	S.
Oct. 3	Disapp. B.A.C. 7063	Sheepshanks Equat.	120	"	8 53 43·85	AC.
3	" "	Astrographic Equat.	225	"	8 53 42·90	S.
8 (*g*)	Reapp. W.B.I. 209	Sheepshanks Equat.	120	"	13 19 (20·74)	H.

Notes.

The apertures of these instruments are as follows: 28-inch Equatorial, 28 inches; Astrographic Equatorial (Guiding Telescope), 10 inches; Sheepshanks, 6·7 inches; Corbett, 6·5 inches; Old Altazimuth, 4 inches.

(*a*) Instantaneous.

(*b*) Misty. Star faded gradually.

(*c*) The Moon's dark limb was easily visible. The star appeared projected within limb before disappearance.

(*d*) Occultation of Saturn. The planet was very tremulous before the occultation, but definition improved somewhat during disappearance. The times noted are those of tangency of the elliptical outlines of the ring and ball with the limb of the Moon. The times enclosed within brackets are presumably erroneous.

(*e*) The observer noted 'Probably late.'

(*f*) Cloudy. Saturn very faint and unsteady. Not considered a good observation.

(*g*) The time noted was considered uncertain, and is evidently erroneous.

The initials L., H., AC., B., WB., R., HF., S., PM., are those of Mr. Lewis, Mr. Hollis, Mr. Crommelin, Mr. Bryant, Mr. Bowyer, Mr. Rendell, Mr. Furner, Mr. Showell, and Mr. Melotte respectively.

Royal Observatory, Greenwich:
1901 *January* 11.

Observations of the Solar Eclipse of 1900 *May* 28, *made at the Royal Observatory, Greenwich.*

(*Communicated by the Astronomer-Royal.*)

Owing to clouds the first contact could not be observed. There were, however, frequent clear intervals during the eclipse, and observations of limbs and cusps in Azimuth and Zenith Distance were made with the New Altazimuth (1) in Azimuth 70° West, (2) in the Prime Vertical, as follows :—

Azimuth 70° *W.*

Day.	Mean Solar Time.	Object.	Observed Az. or Z.D.	Secs. of Tab. A.Z. or Z.D.	Error of Tab. Az. or Z.D.	Observer.
	h m s		° ′ ″	″	″	
May 28	3 9 20·64	N. Cusp Azimuth	Az. 69 51 24·87	Az. 24·63	−0·24	HF.
	3 9 53 53	N. Cusp Z.D.	Z.D. 47 50 18·95	Z.D. 18·73	−0·22	,,
	3 11 12·63	S. Cusp Azimuth	Az. 69 50 48·28	Az. 48·29	+0·01	,,
	3 11 46·08	S. Cusp Z.D.	Z.D. 48 15 53·18	Z.D. 55·48	+2·30	,,
	3 12 42·06	⊙ Second Limb	Az. 69 59 19·23	Az. 16·48	−2·75	,,

Prime Vertical.

Day.	Mean Solar Time.	Object.	Observed Az. or Z.D.	Secs. of Tab. A.Z. or Z.D.	Error of Tab. Az. or Z.D.	Observer.
	h m s		° ′ ″	″	″	
May 28	4 42 28·93	⊙ First Limb	Az. 89 59 32·60	Az. 30·17	−2·43	H.F.
	4 43 37·57	⊙ Lower Limb	Z.D. 62 18 33 09	Z.D. 33·49	+0·40	,,
	4 44 38·87	☽ First Limb	Az. 89 57 8·06	Az. 6·63	−1·43	,,
	4 45 7·78	N. Cusp Azimuth	Az. 90 1 46·21	Az. 40·44	−5·77	,,
	4 45 48·72	S. Cusp Z.D.	Z.D. 62 27 55·02	Z.D. 50 02	−5·00	,,
	4 46 11·83	S. Cusp Azimuth	Az. 90 8 7·46	Az. 5·76	−1·70	,,

The semi-diameters employed are deduced from the following mean values :—

(1) For the Sun from Auwers' value 16′ 1″·18 deduced from Greenwich meridian observations.

(2) For the Moon from L. Struve's value 15′ 32″·65 deduced from occultations during lunar eclipses.

Six photographs of the eclipse were obtained with the Dallmeyer photo-heliograph, the times of exposure being automatically recorded on a chronograph.

The following observations of the last contact were obtained :—

Phenomenon.	Telescope.	Aperture.	Power.	Mean Solar Time.	Observer.	Time from *Naut. Almanac.*
				d h m s		h m
Last contact	28-inch Equat.	20 inches	670	May 28 4 57 25·91	L.	4 57·5
"	Old Altazimuth	4 inches	100	4 57 22·23	H.	
"	Sheepshanks Equat.	6·7 inches	120	4 57 25·09	B.	
"	Finder of Astrog. Equat.	2½ inches	12	4 57 21·2	W.	

The initials L., H., B., HF., W., are those of Mr. Lewis, Mr. Hollis, Mr. Bryant, Mr. Furner, and Mr. Witchell respectively.

Royal Observatory, Greenwich :
1901 *January* 11.

Light Curve of S Aræ (Chandler 6429).
By Alex. W. Roberts, D.Sc.

One of the most remarkable short-period variables in the southern hemisphere is the star

C.P.D. $-49°$, 10361,

recently discovered by Mr. Innes.

As soon after its discovery as possible, regular observations of it were begun at Lovedale with the $3\frac{1}{4}$-inch telescope. The earlier observations were made near the star's setting, and accordingly only isolated observations could be secured. These yielded apparently a period of a little over seven days.

When morning observations were possible, more continuous observations were got, and these indicated that the short period determined at the close of 1899 was in error.

A reduction of all the 1900 observations, over 200 in number, yields a period of

$10^{h}\ 50^{m}\ 45^{s}$.

With this period the observations made were grouped in twenty sets.

The following table gives the average magnitude of each set; also the magnitudes indicated by a mean continuous curve drawn through the observed places.

This mean curve is shown in Plate 6. The residuals between the observed and mean places are given in column 5, and the number of observations in each set in column 6.

The average departure of a single set of observations from the mean value is $0^{m}{\cdot}033$.

No.	Date G.M.T.				Observed Mag.	Mean Mag.	R.	No. of Obs.
		d	h	m	m	m	m	
1	1900 Jan.	1	0	44	10·37	10·39	−0·02	9
2		1	2	3	10·59	10·55	+0·04	11
3		1	2	47	10·63	10·64	−0·01	17
4		1	3	48	10·76	10·73	+0·03	15
5		1	4	33	10·73	10·79	−0·06	12
6		1	5	44	10·84	10·83	+0·01	7
7		1	6	34	10·74	10·77	−0·03	18
8		1	7	23	10·67	10·66	+0·01	11
9		1	7	50	10·50	10·51	−0·01	15
10		1	8	6	10·31	10·30	+0·01	10
11		1	8	13	10·08	10·10	−0·02	13
12		1	8	27	9·80	9·85	−0·05	15
13		1	8	44	9·66	9·57	+0·09	9

No.	Date G.M.T. d h m	Observed Mag. m	Mean Mag. m	R. m	No. of Obs.
14	1900 Jan. 1 8 52	9·52	9·55	−0·03	7
15	1 9 2	9·70	9·62	+0·08	10
16	1 9 17	9·73	9·76	−0·03	9
17	1 9 27	9·88	9·85	+0·03	6
18	1 9 53	10·02	10·05	−0·03	10
19	1 10 12	10·22	10·17	+0·05	10
20	1900 Jan. 1 10 38	10·25	10·27	−0·02	15

The marked characteristic of the light curve of *S Aræ* is its rapid decrease, immediately after maximum phase, and its consequent slow rate of variation at minimum.

Its rapid ascent to a maximum is notable enough, $0^{m}\cdot02$ every minute, but this is not abnormal considering the shortness of the star's period.

The form of the light curve from maximum to minimum, however, departs considerably from the usual type of short-period variation ; still the departure is not so complete as to disassociate this star from this class of variable stars. Indeed the explanation offered by more than one observer as to the cause of variation of this type meets in no incomplete way the variation of *S Aræ*.

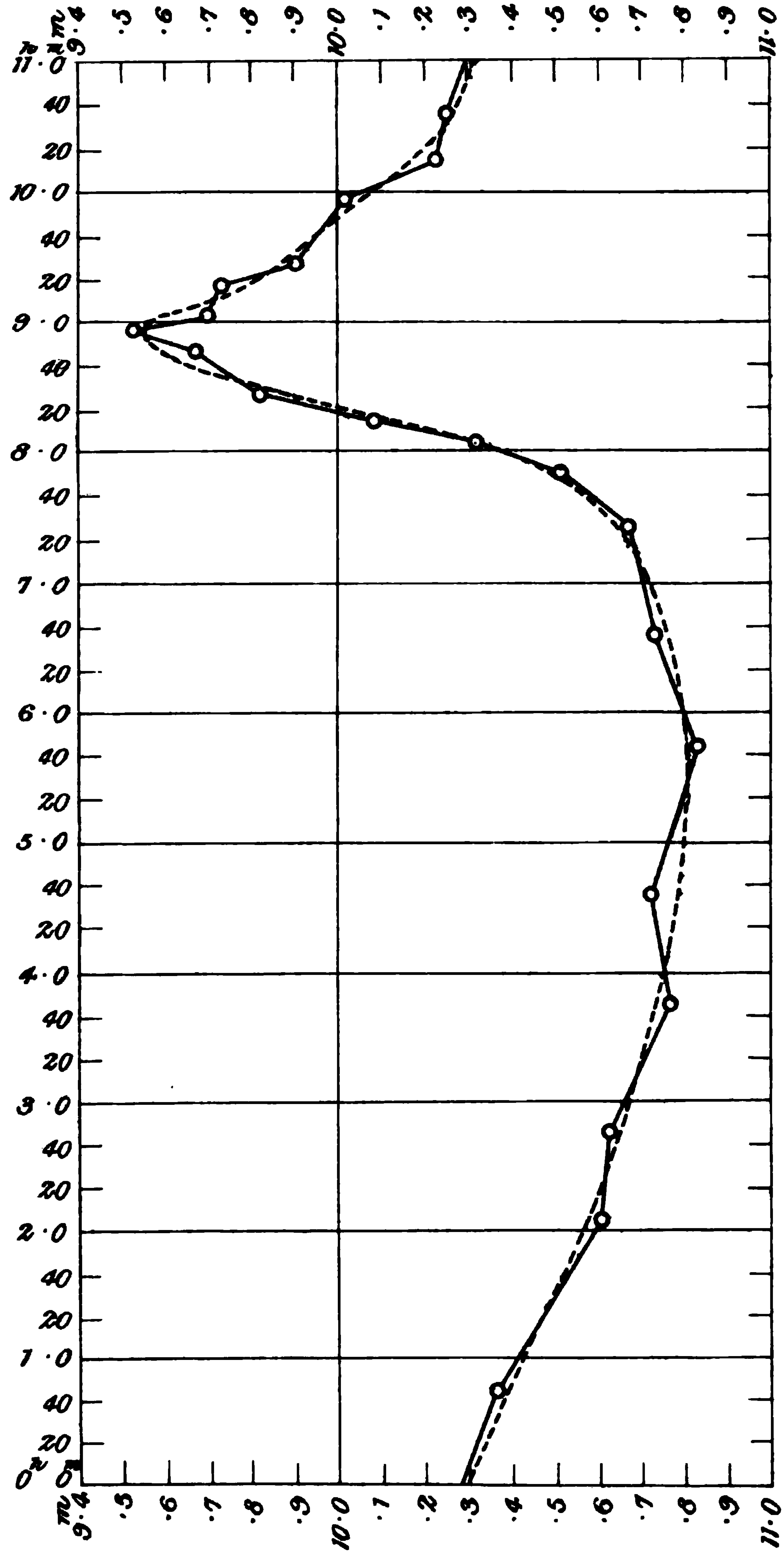
In the *Astrophysical Journal*, vol. ii. p. 283, I pointed out that if we consider short-period variables to be binary systems, with very eccentric orbits, we have all the conditions for the well-known phenomena of short-period variation : a rapid rise to maximum ; a slow descent to minimum, a descent becoming still slower as the star approaches minimum ; and continuous variation.

An eccentricity of 0·5 would yield sufficient periodic change in the mutual tidal force of each component of *S Aræ* to cause an alteration in brightness of at least one magnitude ; while even a retardation of a few minutes of the maximum tidal effect after periastron passage would produce the rapid rise to maximum brightness that is so markedly a feature of the variation of *S Aræ*, as well as of all stars of this type.

It may be of service to give in a complete form the elements of variation of *S Aræ* resulting from the Lovedale measures.

Period	$10^{h}\ 50^{m}\ 45^{s}$
Epoch of max. ...	1900 January $1^{d}\ 4^{h}\ 12^{m}$ (G.M.T.)
Epoch of min.	1 7 20
Ratio of I to D	0·29
Limits of variation	$9^{m}\cdot53$ to $10^{m}\cdot84$

Lovedale: 1900 December.



Light curve of S Aræ. (Chandler 6429)
1900 Jany. 1 (G.M.T.)

UNIVERSITY
OF

MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

VOL. LXI. FEBRUARY 8, 1901. No. 4

E. B. KNOBEL, Esq., PRESIDENT, in the Chair.

A. Otto Hilger, 204 Stanhope Street, Hampstead Road, N.W.; and

The Rev. George Vickars-Gaskell, Grange-over-Sands, North Lancashire,

were balloted for and duly elected Fellows of the Society.

The following Candidates were proposed for election as Fellows of the Society, the names of the proposers from personal knowledge being appended :—

Francis Alfred Laxton Kitchin, B.A. (late scholar of Pembroke College, Cambridge), Naval Instructor, R.N., H.M.S. *Britannia*, Dartmouth (proposed by H. H. Turner); and

Richard Coad Pryor, M.A. (Trinity College, Cambridge), The Rectory, Grafton Regis, Stony Stratford (proposed by J. W. L. Glaisher).

REPORT OF THE COUNCIL TO THE EIGHTY-FIRST ANNUAL GENERAL MEETING OF THE SOCIETY.

The following table shows the progress and present state of the Society :—

	Compounders	Annual Subscribers	Total Fellows	Associates	Patron	Grand Total
1899 December 31	253	382	635	48	1	684
Since elected	+ 2	+ 15	...	...	...	...
Deceased	− 7	− 6	...	− 2	...	...
Resigned	...	− 9	...	...	...	...
Removals	+ 2	− 2	...	...	...	...
Expelled	...	− 5	...	...	...	...
1900 December 31	250	375	625	46	1	672

Mr. Maw's Account as Treasurer of the Royal

RECEIPTS.

	£	s.	d.	£	s.	d.
Balances, 1900 January 1:—						
At Bankers', as per Pass-book	400	10	2			
Cheques not credited till 1900	6	6	0			
In hand of Assistant Secretary on account of Council Grant for Purchase of Books ...	8	18	9			
In hand of Assistant Secretary on Petty Cash Account	18	11	3			
				434	6	2
Dividends on £1,250 Metropolitan 3-per-cent. Stock	35	15	9			
Dividends on £932 19 0 Metropolitan 2½-per-cent. Stock	22	5	3			
Dividends on £3,400 East Indian Railway 3-per-cent. Debenture Stock	97	6	6			
Dividends on £3,200 London and North-Western Railway 3-per-cent. Debenture Stock	92	8	0			
Dividends on £3,600 Midland Railway 2½-per-cent. Debenture Stock	86	12	6			
Dividends on £1,860 Gas Light and Coke Co. 3-per-cent. Debenture Stock	53	14	2			
Dividends on £1,100 Commercial Gas Co. 4½-per-cent. Debenture Stock	47	4	7			
				435	6	9
Received on account of Subscriptions:—						
Arrears	119	14	0			
Annual Contributions for 1900	577	10	0			
" " 1901	10	10	0			
Admission Fees	35	14	0			
First Contributions	19	19	0			
				763	7	0
Composition Fees				105	0	0
Sales of Publications:—						
At Williams and Norgate's, 1899	32	19	10			
At Society's Rooms, 1900	47	10	9			
Sales of Photographs, 1900	34	13	6			
				115	4	1
Income Tax refunded by Commissioners of Inland Revenue				14	12	5
Due to Assistant Secretary on account of Turnor & Horrox Fund				2	0	11
				£1,869	17	4

Astronomical Society, from 1900 *January* 1 *to December* 31.

EXPENDITURE.

	£	s.	d.	£	s.	d.
Assistant Secretary: Salary	250	0	0			
" " for assistance in editing Society's Publications ...	50	0	0			
				300	0	0
House Duty	2	12	6			
Fire Insurance	9	9	6			
				12	2	0
Printing, &c., *Monthly Notices*	468	17	3			
" List of Fellows and Miscellaneous ...	30	1	3			
Matrices for Special Type for Fractions (half-cost)	12	10	0			
Engraving Blocks for *Monthly Notices*	3	13	10			
				515	2	4
Computation of Ephemerides	15	0	0			
Preparation of Supplementary Library Catalogue...	15	0	0			
				30	0	0
Council Grant: Purchases for Library	8	18	9			
Turnor and Horrox Fund: Purchases for Library	12	0	11			
Binding Books in Library	46	5	3			
				67	4	11
Reproduction of Photographs				31	14	5
Eclipse Expedition: Grant to Assistant Secretary				30	0	0
Repairs, &c. to Instruments				26	2	0
Clerk's Wages	45	10	0			
Postage and Telegrams	63	19	9			
Carriage of Parcels, &c.	3	13	6			
Stationery (Spottiswoode & Co.)	5	16	0			
Stationery and Office Expenses	3	3	10			
				122	3	1
Expenses of Meetings	20	0	0			
Lantern Expenses	6	11	6			
Time Signal: Rental of Wire	5	0	0			
				31	11	6
House Expenses	67	6	5			
Coals and Gas	52	1	8			
Electric Light Expenses	9	1	9			
Fittings, Repairs, &c.	17	0	0			
Sundries	3	12	8			
				149	2	6
Lee and Janson Fund Grant				5	0	0
Bankers' Deductions on Cheques				0	1	9
Balances, 1900 December 31:—						
At Bankers', as per Pass-book	535	4	4			
Cheque not credited till 1901	4	4	0			
In hand of Assistant Secretary on Petty Cash Account	10	4	6			
				549	12	10
				£1,869	17	4

0 2

Report of the Auditors.

We have examined the Treasurer's accounts for the year 1900, and have found and certified the same to be correct. The cash in hand on December 31, 1900, including the balance at the bankers', &c., amounted to £549 12*s.* 10*d.*

During the past year no changes were made in the investments of the Society.

The books, instruments, and other effects in the possession of the Society have been examined, and they appear to be in a satisfactory condition.

We have laid on the table a list of the names of those Fellows who are in arrear for sums due at the last Annual General Meeting of the Society, with the amount due against each Fellow's name.

(Signed) RICHARD INWARDS,
HAROLD SEWARD,
DAVID SMART.

January 8, 1901.

Trust Funds.

The Turnor Fund: A sum of £464 18*s.* East Indian Railway 3-per-cent. Debenture Stock; the interest to be used in the purchase of books for the Library.

The Horrox Memorial Fund: A sum of £103 6*s.* East Indian Railway 3-per-cent. Debenture Stock; the interest to be used in the purchase of books for the Library.

The Lee and Janson Fund: A sum of £334 10*s.* 9*d.* East Indian Railway 3-per-cent. Debenture Stock; the interest to be given by the Council to the widow or orphan of any deceased Fellow of the Society who may stand in need of it.

The Hannah Jackson (née Gwilt) Fund: A sum of £309 18*s.* 6*d.* East Indian Railway 3-per-cent. Debenture Stock; the interest to be given in Medals or other awards, in accordance with the terms of the Trust.

Assets and Present Property of the Society, 1901 *January* 1.

	£	s.	d.	£	s.	d.
Balances, 1900 December 31:—						
At Bankers', as per Pass-book	535	4	4			
Cheque not credited till 1901	4	4	0			
In hand of Assistant Secretary on Petty Cash Account	10	4	6			
	549	12	10			
Less due to Assistant Secretary on Account of Turnor and Horrox Fund	2	0	11			
				547	11	11
Due on account of Subscriptions:—						
1 Contribution of 5 years' standing	10	10	0			
2 Contributions of 4 "	16	16	0			
12 " 3 "	75	12	0			
31 " 2 "	130	4	0			
57 " 1 year's standing	119	14	0			
2 Admission Fees and First Contributions ...	6	6	0			
	359	2	0			
Less 5 Contributions paid in advance ...	10	10	0			
				348	12	0
Due from Messrs. Williams and Norgate for sales of Publications during 1900				11	5	7

£3,400 East Indian Railway 3-per-cent. Debenture Stock, including the Turnor Fund, the Horrox Memorial Fund, the Lee and Janson Fund, and the Hannah Jackson (née Gwilt) Fund.

£3,200 London and North Western Railway 3-per-cent. Debenture Stock.

£3,600 Midland Railway 2½-per-cent. Debenture Stock.

£1,860 Gas Light and Coke Co. 3-per-cent. Debenture Stock.

£1,100 Commercial Gas Company 4½-per-cent. Debenture Stock.

£1,250 Metropolitan 3-per-cent. Stock.

£932 19 0 Metropolitan 2½-per-cent. Stock.

Astronomical and other Manuscripts, Books, Prints, and Instruments.

Furniture, &c.

Stock of Publications of the Society.

One Gold Medal.

Stock in hand of volumes of the *Memoirs*:—

Vol.	At Society's Rooms	At Williams & Norgate's	Vol.	At Society's Rooms	At Williams & Norgate's
I. Part 1	8	...	XXXI.	134	...
I. Part 2	42	...	XXXII.	145	...
II. Part 1	51	3	XXXIII.	154	...
II. Part 2	16	3	XXXIV.	157	...
III. Part 1	65	1	XXXV.	104	2
III. Part 2	82	1	XXXVI.	187	8
IV. Part 1	77	3	XXXVII. Part 1	330	7
IV. Part 2	89	3	XXXVII. Part 2	278	8
V.	100	3	XXXVIII.	263	1
VI.	117	6	XXXIX. Part 1	228	3
VII.	140	3	XXXIX. Part 2	233	3
VIII.	124	3	XL.	248	...
IX.	130	3	XLI.	392	...
X.	142	...	XLII.	224	3
XI.	147	...	XLIII.	222	...
XII.	152	...	XLIV.	206	1
XIII.	150	...	XLV.	238	...
XIV.	358	...	XLVI.	214	2
XV.	231	...	XLVII. Part 1	2	...
XVI.	157	1	XLVII. Part 2	18	...
XVII.	140	1	XLVII. Part 3	2	...
XVIII.	132	1	XLVII. Part 4	8	...
XIX.	143	...	XLVII. Part 5	8	...
XX.	133	1	XLVII. Part 6	9	...
XXI. Part 1	244	...	XLVII.	195	1
XXI. Part 2	98	...	XLVIII. Pt. 1	227	2
XXI. 1 & 2 (together)	54	...	XLVIII. Pt. 2	229	1
XXII.	156	...	XLIX. Part 1	357	...
XXIII.	141	...	XLIX. Part 2	241	...
XXIV.	147	1	L.	233	...
XXV.	153	...	LI.	265	1
XXVI.	163	1	LII.	319	1
XXVII.	417	1	LIII.	340	...
XXVIII.	371	...	Index to *Memoirs*	619	1
XXIX.	395	1			
XXX.	147	1			

Stock in hand of volumes of the *Monthly Notices*:—

Vol.	At Society's Rooms	At Williams & Norgate's	Vol.	At Society's Rooms	At Williams & Norgate's
I.	54	...	XXXII.	106	5
II.	56	...	XXXIII.	86	...
III.	...	...	XXXIV.	65	1
IV.	...	...	XXXV.	51	...
V.	...	...	XXXVI.	25	1
VI.	41	...	XXXVII.	31	3
VII.	2	...	XXXVIII.	95	2
VIII.	152	2	XXXIX.	95	...
IX.	24	2	XL.	104	3
X.	171	1	XLI.	103	5
XI.	182	...	XLII.	111	1
XII.	105	2	XLIII.	108	2
XIII.	176	2	XLIV.	110	2
XIV.	175	3	XLV.	114	1
XV.	167	2	XLVI.	107	...
XVI.	153	1	XLVII.	122	2
XVII.	165	...	XLVIII.	117	...
XVIII.	242	...	XLIX.	108	7
XIX.	51	...	L.	108	10
XX.	31	...	LI.	110	7
XXI.	16	...	LII.	107	11
XXII.	30	...	LIII.	112	15
XXIII.	17	...	LIV.	111	14
XXIV.	22	...	LV.	124	...
XXV.	13	...	LVI.	122	3
XXVI.	9	...	LVII.	129	3
XXVII.	3	...	LVIII.	127	1
XXVIII.	70	...	LIX.	131	4
XXIX.	50	...	1st Index ...	543	1
XXX.	61	2	2nd „ ...	798	...
XXXI.	90	...			

LIBRARY CATALOGUE	542	...
„ „ SUPPLEMENT	487	...

In addition to the above volumes of the *Monthly Notices*, the Society has a considerable stock of separate numbers of nearly all the volumes. With the exception, however, of Vols. XXXVI. to LX., no complete volumes can be formed from the separate numbers in stock.

Celestial Photographs.

The following is a list of reproductions of Celestial Photographs published by the Royal Astronomical Society for sale to the Fellows :—

R.A.S. Ref. No.	Subject.	Photographed by
1	Total Solar Eclipse, 1889 January 1	W. H. Pickering
2	Total Solar Eclipse, 1893 April 16	J. M. Schaeberle
3	Total Solar Eclipse, 1886 August 29	A. Schuster
4	Nebulæ in the *Pleiades*	Isaac Roberts
5	Nebula M 74 *Piscium*	Isaac Roberts
6	Great Nebula in *Orion*	Isaac Roberts
7	Milky Way near M 11	E. E. Barnard
8	Milky Way near Cluster in *Perseus*	E. E. Barnard
9	Comet *c* 1893 IV. (Brooks), 1893 October 21	E. E. Barnard
10	Comet *a* 1892 I. (Swift), 1892 April 7	E. E. Barnard
11	Nebula about η *Argûs*	David Gill
12	Portion of Moon (Hyginus-Albategnius)	Lœwy and Puiseux
13	Comet *c* 1893 IV. (Brooks), 1893 October 22	E. E. Barnard
14	Comet *c* 1893 IV. (Brooks), 1893 October 20	E. E. Barnard
15	Comet *c* 1893 IV. (Brooks), 1893 November 10	E. E. Barnard
16	Comet *a* 1892 I. (Swift), 1892 April 26	E. E. Barnard
17	Comet *f* 1892 III. (Holmes), 1892 November 10	E. E. Barnard
18	Comet *a* 1892 I. (Swift), 1892 April 18	E. E. Barnard
19	Portion of Moon (Alps, Apennines, &c.)	Lœwy and Puiseux
20	Nebula in *Andromeda*	Isaac Roberts
21	*Jupiter*, 1892 September 26	Lick Observatory
22	Cluster M 13 *Herculis*	W. E. Wilson
23	Total Solar Eclipse, 1893 April 16 (5 sec.)	J. Kearney
24	Total Solar Eclipse, 1893 April 16 (20 sec.)	J. Kearney
25	The Moon (Age $7^d\ 3^h$)	Lick Observatory
26	The Moon (Age $12^d\ 6\frac{1}{2}^h$)	Lick Observatory
27	The Moon (Age $16^d\ 18^h$)	Lick Observatory
28	The Moon (Age $23^d\ 8^h$)	Lick Observatory
29	The Sun, 1892 February 13	Roy. Obs., Greenwich
30	The Sun, 1892 July 8	Roy. Obs., Greenwich
31	Portion of Moon (Region of Maginus)	Lœwy and Puiseux

R.A.S. Ref. No.	Subject.	Photographed by
32	The Moon (Age $14^d\ 1^h$)	Lick Observatory
33	Portion of Moon (Ptolemæus, &c.)	Lick Observatory
34	Portion of Moon (Mare Serenitatis)	Lick Observatory
35	Portion of Moon (Clavius, Licetus, &c.)	Lick Observatory
36	Portion of Moon (Regiomontanus, &c.)	Lick Observatory
37	Portion of Moon (Tycho, Thebit, &c.)	Lick Observatory
38	Portion of Moon (Theophilus, &c.)	Lick Observatory
39	Total Solar Eclipse, 1896 August 9 (3 sec.)	S. Kostinsky
40	Total Solar Eclipse, 1896 August 9 (26 sec.)	A. Hansky
41	Cluster M 56 *Lyræ*	
42	Nebulæ M 81, 82 *Ursæ Majoris*	
43	Cluster M 56 *Lyræ* (enlarged)	
44	Solar Corona, 1871 December 12, Baikul	H. Davis
45	Solar Corona, 1875 April 6, Siam	Lockyer and Schuster
46	Solar Corona, 1878 July 29, Wyoming	W. Harkness
47	Solar Corona, 1882 May 17, Egypt	Abney and Schuster
48	Solar Corona, 1883 May 6, Caroline Island	Lawrance and Woods
49	Solar Corona, 1885 September 9, Wellington, N.Z.	Radford
50	Solar Corona, 1886 August 29, Grenada, W.I.	A. Schuster
51	Solar Corona, 1887 August 19, Japan	M. Sugiyama
52	Solar Corona, 1889 January 1, California	W. H. Pickering
53	Solar Corona, 1889 December 22, Cayenne	J. M. Schaeberle
54	Solar Corona, 1893 April 16, Fundium	J. Kearney
55	Solar Corona, 1893 April 16, Brazil	A. Taylor
56	Great Nebula in *Orion*	W. E. Wilson
57	Dumb-bell Nebula, *Vulpecula*	W. E. Wilson
58	Spiral Nebula, *Canes Venatici*	W. E. Wilson
59	Spiral Nebula, *Canes Venatici* (enlarged)	W. E. Wilson
60	Annular Nebula in *Lyra*	W. E. Wilson
61	Meteor Trail and Comet Brooks, 1893 November 13	E. E. Barnard
62	Total Solar Eclipse, 1898 January 22 (5 sec.)	W. H. M. Christie
63	Total Solar Eclipse, 1898 January 22 (20 sec.)	W. H. M. Christie
64	Solar Corona, 1896 August 9, Novaya Zemlya	G. Baden-Powell
65	Solar Corona, 1898 January 22, Pulgaon, India	E. H. Hills
66	Nebula in *Andromeda*	Roy. Obs., Greenwich
67	Spectrum of Sun's limb, 1898 January 22	E. H. Hills
68	Annular Nebula, *Lyra*	Lick Observatory
69	Dumb-bell Nebula, *Vulpecula*	Lick Observatory
70	Spiral Nebula, *Canes Venatici*	Lick Observatory

R.A.S. Ref. No.	Subject.	Photographed by
71	Spiral Nebula, *Ursa Major*	Lick Observatory
72	Trifid Nebula, *Sagittarius*	Lick Observatory
73	Great Nebula in *Orion*	Lick Observatory
74	Cluster M 13 *Herculis*	Lick Observatory
75	Solar Surface with Faculæ	G. E. Hale
76	Faculæ and Prominences	G. E. Hale
77	Total Solar Eclipse, 1898 Jan. 22 (¾ sec.)	W. H. M. Christie
78	Nebula H V. 14 *Cygni*	W. E. Wilson

Nos. 44–55 and Nos. 64 and 65 form a series of corona photographs, oriented and reduced to the same scale.

The above photographs are now on sale to Fellows as prints, either platinotype or aristotype, mounted on sunk cut-out mounts, measuring 12 inches by 10 inches, and also as lantern slides. Nos. 44–55 and Nos. 64 and 65 are also supplied as transparencies, 6¼ inches square.

Price of prints, 1*s.* 6*d.* each; lantern slides, 1*s.* each; packing and postage extra.

Unmounted prints, 1*s.* each, can be obtained to order.

Transparencies, 6¼ inches square (Nos. 44–55 and Nos. 64 and 65), 3*s.* 6*d.* each.

Orders to be addressed to W. H. Wesley, Burlington House, London, W. In ordering prints or slides the R.A.S. Reference No. only need be quoted, but in the case of prints it should be stated whether platinotypes or aristotypes are required.

Instruments belonging to the Society.

A brief description of the chief instruments and other particulars relating to them will be found in *Monthly Notices*, vol. xxxvi. p. 126.

No. 1. The *Harrison* clock.
„ 2. The *Owen* portable circles, by Jones.
„ 3. The *Beaufoy* circle.
„ 4. The *Beaufoy* transit instrument.
„ 5. The *Herschel* 7-foot telescope.
„ 6. The *Greig* universal instrument, by Reichenbach and Ertel. The transit telescope, by Utzschneider and Fraunhofer, of Munich.
„ 7. The *Smeaton* equatorial.
„ 8. The *Cavendish* apparatus.
„ 9. The 7-foot Gregorian telescope (late Mr. Shearman's).
„ 10. The variation transit instrument (late Mr. Shearman's).

No. 11. The universal quadrat, by Abraham Sharp.
„ 12. The *Fuller* theodolite.
„ 13. The standard scale, by Troughton and Simms.
„ 14. The *Beaufoy* clock, No. 1.
„ 15. The *Beaufoy* clock, No. 2.
„ 16. The *Wollaston* telescope.
„ 17. The *Lee* circle.
„ 18. The *Sharpe* reflecting circle.
„ 19. The *Brisbane* circle.
„ 20. The *Baker* universal equatorial.
„ 21. The *Reade* transit.
„ 22. The *Matthew* equatorial, by Cooke.
„ 23. The *Matthew* transit instrument.
„ 24. The *South* transit instrument.
„ 25. A sextant, by Bird (formerly belonging to Captain Cook).
„ 26. A globe showing the precession of the equinoxes.

The *Sheepshanks* collection :—

„ 27. (1) 30-inch transit instrument, by Simms, with level and two iron stands.
„ 28. (2) 6-inch transit theodolite, with circles divided on silver; reading microscopes, both for altitude and azimuth; cross and siding levels; magnetic needle; plumb-line; portable clamping foot and tripod stand.
„ 29. (3) Equatorial stand and clock movement for $4\frac{6}{10}$-inch telescope (telescope lost); double-image micrometer; two wire micrometers; object-glass micrometer.
„ 30. (4) $3\frac{1}{4}$-inch achromatic telescope, with equatorial stand; double-image micrometer; one terrestrial and three astronomical eyepieces.
„ 31. (5) $2\frac{3}{4}$-inch achromatic telescope, with stand; one terrestrial and three astronomical eyepieces.
„ 33. (7) 2-foot navy telescope.
„ 34. (8) Transit instrument of 45 inches focal length, with iron stand and also Y's for fixing to stone piers; two axis levels.
„ 35. (9) Repeating theodolite, by Ertel, with folding tripod stand.
„ 36. (10) 8-inch pillar sextant, by Troughton, divided on platinum, with counterpoise stand and artificial horizon.
„ 37. (11) Portable zenith telescope and stand, $2\frac{3}{4}$-inch aperture and 26 inches focal length; 10-inch horizontal circle and 8-inch vertical circle, reading to 10″ by two verniers to each circle.
„ 38. (12) 18-inch Borda repeating circle, by Troughton, $2\frac{1}{8}$-inch aperture and 24 inches focal length; the circles divided on silver, the horizontal circle being read by four verniers, and the vertical circle by three verniers, each to 10″.

No. 39. (13) 8-inch vertical repeating circle, with diagonal telescope, by Troughton and Simms; circle divided on silver, reading to 10″; a 5-inch circle at eye-end, reading to single minutes; horizontal circle 9 inches diameter in brass to single minutes.

„ 40. (14) A set of surveying instruments, consisting of a 12-inch theodolite for horizontal angles only, reading to 10″; two sets of adjusting plates; tripod stand with enclosed telescope; heavy stand for theodolite; Y-piece of level; two large and three small ground-glass bubbles divided; level collimator, object-glass 1⅝-inch diameter and 16 inches focal length; micrometer eyepiece, comb, and wires; mercury bottle and trough.

„ 41. (15) Level collimator, with object-glass 1⅞-inch diameter and 16 inches focal length; stand, rider-level, and fittings.

„ 42. (16) 10-inch reflecting circle by Troughton, reading by three verniers to 20″; counterpoise stand; artificial horizon, with mercury; two tripod stands.

„ 43. (17) Hassler's reflecting circle, by Troughton, with counterpoise stand.

„ 44. (18) 6-inch reflecting and repeating circle, by Troughton and Simms, contained in three boxes, two of which form stands. Circle divided on silver, reading to single minutes; two inside arcs divided to single degrees, 150 degrees on each side; artificial horizon and mercury.

„ 45. (19) 5-inch reflecting and repeating circle, by Lenoir, of Paris.

„ 46. (20) Reflecting circle, by Jecker, of Paris, 11 inches in diameter, with one vernier reading to 15″.

„ 47. (21) Box sextant; reflecting plane and level.

„ 48. (22) Prismatic compass, by Troughton and Simms.

„ 49. (23) Mountain barometer.

„ 50. (24) Prismatic compass, by Thomas Jones, mounted with a cylindrical lens.

„ 51. (25) Ordinary 4½-inch compass with needle.

„ 52. (26) Dipping needle, by Robinson.

„ 53. (27) Compass needle, mounted for variation.

„ 54. (28) Magnetic intensity needle, by Meyerstein, of Göttingen; a strongly fitted brass box with heavy magnet; filar suspension.

„ 55. (29) Box of magnetic apparatus.

„ 56. (30) Hassler's reflecting circle, by Troughton; a 10½-inch reflecting and repeating circle, with stand and counterpoise, divided on platinum with two movable and two fixed indices; four verniers reading to 10″.

„ 57. (31) Box sextant and glass plane artificial horizon, by Troughton and Simms.

„ 58. (32) Plane 2⅜-inch speculum, artificial horizon and stand.

No. 59. (33) $2\frac{1}{2}$-inch circular level horizon, by Dollond.
" 60. (34) Artificial horizon, roof, and trough; the trough $8\frac{1}{4}$ by $4\frac{1}{2}$ inches; tripod stand.
" 61. (35) Set of drawing instruments, consisting of 6-inch circular protractor and common protractor, T-square; one beam compass.
" 62. (36) A pantograph.
" 63. (37) A noddy.
" 64. (38) A small Galilean telescope with object-glass of rock crystal.
" 65. (39) Five levels.
" 66. (40) 18-inch celestial globe.
" 67. (41) Varley stand for telescope.
" 69. (43) Telescope, with object-glass of rock crystal.
" 71. Portable altazimuth tripod.
" 72. Four polarimeters.
" 74. Registering spectroscope, with one large prism.
" 76. Two five-prism direct-vision spectroscopes.
" 78. $9\frac{1}{4}$-inch silvered-glass reflector and stand, by Browning.
" 79. Spectroscope.
" 80. A small box, containing three square-headed Nicol's prisms; two Babinet's compensators; two double-image prisms; three Savarts; one positive eyepiece, with Nicol's prism; one dark wedge.
" 81. A back-staff, or Davis' quadrant.
" 82. A nocturnal or star dial.
" 83. An early non-achromatic telescope, of about 3 feet focal length, in oak tube, by Samuel Scatliffe, London.
" 84. A Hollis observing chair.
" 85. Double-image micrometer, by Troughton and Simms.
" 86. $4\frac{1}{2}$-inch Gregorian reflecting telescope, by Short, with altazimuth stand and 6-inch altitude and azimuth circles and two eyepieces.
" 87. $3\frac{1}{4}$-inch Gregorian reflecting telescope with wooden tripod stand.
" 88. Pendulum, with 5-foot brass suspension rod, working on knife-edges, by Thomas Jones.
" 89. A Rhabdological Abacus. A contrivance invented by Mr. H. Goodwyn, consisting of a box filled with compartments, in which are square rods covered with numbers, which can be arranged so as to facilitate the labour of multiplying high numbers.
" 90. An Arabic celestial globe of bronze, $5\frac{3}{4}$ inches in diameter.
" 91. Astronomical time watch-case, by Professor Chevallier.
" 92. 2-foot protractor, with two movable arms, and vernier.
" 93. Beam compass, in box.
" 94. 2-foot navigation scale.
" 95. Stand for testing measures of length.

No. 96. Artificial planet and star, for testing the measurement of a fixed distance at different position angles.
„ 97. 12-cell Leclanché battery.
„ 98. 2-foot 6-inch navy telescope, with object-glass $2\frac{1}{2}$ inches, by Cooke, with portable wooden tripod stand.
„ 99. 12-inch transit instrument, by Fayrer and Son, with level and portable stand.
„ 100. 9-inch transit instrument, with level and iron stand.
„ 101. Small equatorial sight instrument, by G. Adams, London.
„ 102. Sun-dial, by Troughton.
„ 103. Sun-dial, by Casella.
„ 104. Sun-dial.
„ 105. Box sextant, by Troughton and Simms.
„ 106. Prismatic compass, by Schmalcalder, London.
„ 107. Compass, by C. Earle, Melbourne.
„ 108. Prismatic compass, by Negretti and Zambra.
„ 109. Dipleidoscope, by E. Dent.
„ 110. Abney level, by Elliott.
„ 111. Pocket spectroscope, by Browning.
„ 112. Universal sun-dial.
„ 113. Double sextant, by Jones.
„ 114. Two models, illustrating the effects of circular motions.
„ 115. A cometarium.
„ 117. Two old sun-dials.
„ 118. A $10\frac{1}{2}$-inch sixteenth-century celestial globe, on bronze tripod stand.
„ 119. Specimens of diffraction gratings, by Prof. W. A. Rogers.
„ 120. A 6-prism spectroscope, by Browning.
„ 121. Spitta's improved maximum and minimum thermometer.
„ 122. A 6-inch speculum, with flat; the speculum said to be by Sir W. Herschel, and re-figured by Sir J. Herschel.
„ 123. A 6-inch refracting telescope, by Grubb, with 3 eyepieces.
„ 124. Position micrometer, by Cooke.
„ 125. A 6-inch refracting telescope, by Simms, with eyepieces and solar diagonal.
„ 126. $3\frac{1}{2}$-inch portable refracting telescope, by Tulley, with tripod stand.
„ 127. Globe representing the visible surface of the Moon, by John Russell, R.A. (1797).
„ 128. Bichromate battery and Ruhmkorff coil.
„ 129. Slater's improved armillary sphere.
„ 130. 10-inch brass pillar sextant with counterpoise stand, by Troughton.
„ 131. Double box sextant, by Cary.
„ 132. Equatorially mounted camera with $2\frac{1}{2}$-inch portrait lens and telephotographic enlarging lens by Dallmeyer;

iron pillar. [Presented by the executors of the late Sidney Waters.]

No. 133. $3\frac{1}{2}$-inch equatorial by Ross, with tall tripod stand, equatorial mounting, eyepieces, and micrometer. [Presented by Mrs. Mann.]

„ 134. Old transit instrument, 2-inch aperture and 3 feet focal length (without stand), formerly belonging to Dr. Longfield, of Cork. [Presented by the executors of the late R. J. Lecky.]

„ 135. Globe of Mars, by E. M. Antoniadi. [Presented by M. Antoniadi.]

„ 136. A small universal instrument by W. and S. Jones, London; the telescope $1\frac{1}{2}$-inch aperture and 15 inches focal length. [Presented by Miss Moore.]

Besides the above, there is the following apparatus available for eclipse work :—

4 Slits for spectroscope.
Abney doublet lens used in photographing the corona.
2 Dallmeyer negative enlarging lenses.
Cœlostat with 16-inch plane mirror.

The following instruments are lent, during the pleasure of the Council, to the undermentioned persons :—

No. 4. The *Beaufoy* transit instrument, to the Observatory, Kingston, Canada.

„ 16. The *Wollaston* telescope, to Mr. R. Inwards.

„ 22. The *Matthew* equatorial, to Mr. C. Thwaites.

„ 23. The *Matthew* transit, to Captain W. Noble.

„ 28. (2) 6-inch theodolite and stand, to Dr. A. A. Common.

„ 29. (3) Equatorial mounting, clock, &c., to the Rev. C. D. P. Davies.

„ „ Wire micrometer (No. 2), to the Rev. C. D. P. Davies.

„ 30. (4) $3\frac{1}{4}$-inch equatorial and stand, to Mr. C. H. Johns.

„ „ Double-image micrometer, to the Rev. W. J. B. Roome.

„ 50. (24) Prismatic compass, to Mr. Maxwell Hall.

„ 57. (31) Box sextant, to Dr. A. A. Common.

„ 69. (43) Telescope with rock-crystal object-glass, to Sir W. Huggins.

„ 72. (c) Polarimeter, to Professor C. Michie Smith.

„ 78. $9\frac{1}{4}$-inch reflector and stand, to the Rev. W. J. B. Roome.

„ 80. Box of polariscopic apparatus, to Mr. H. F. Newall.

„ 98. 2-foot 6-inch navy telescope, to the Rev. J. M. Bacon.

„ 123. 6-inch telescope, by Grubb (object-glass only), to Mr. W. E. Wilson.

„ 125. 6-inch refractor, by Simms, to Dr. A. A. Common.

No. 126. $3\frac{1}{2}$-inch portable telescope, by Tulley, to Mr. T. K. Mellor.

„ 132. The *Waters* equatorial, to Mr. E. W. Maunder.

„ 133. $3\frac{1}{4}$-inch equatorial, by Ross, to Dr. A. W. Roberts.

The Gold Medal.

The Council have awarded the Society's Gold Medal to Professor E. C. Pickering, for his researches on variable stars and his work in astronomical photography. The President will lay before the Society the grounds upon which the award has been founded.

Supplementary Library Catalogue.

A supplement to the catalogue of the Society's Library, containing references to all works added to the Library between June 1884 and June 1898, has been published during the past year. Price to Fellows, 1*s.*

Change in the Form of the Memoirs.

The Council have decided to alter the size of the page of the *Memoirs*, so that in future it shall be uniform in size and in extent of letterpress with the page of the *Philosophical Transactions* of the Royal Society.

The change takes place with Volume LIV., which is now in the press, and will contain the following papers amongst others :—

I. Prof. E. W. Brown, Theory of the Motion of the Moon, containing a new calculation of the expressions for the coordinates of the Moon in terms of the time. Part III., Chapter VI.

II. Mr. William Coleman, Micrometrical Measures of Double Stars, 1897–99.

III. Rev. W. Sidgreaves, On the Connexion between Solar Spots and Earth Magnetic Storms.

The Council have to record with profound regret the death of Her Majesty Queen Victoria, who throughout the whole of Her reign was the Patron of the Society.

The Council have prepared the following Address to be offered to His Majesty King Edward VII.

To the King's Most Excellent Majesty.

May it please Your Majesty,

We, the Royal Astronomical Society, humbly beg leave to approach Your Majesty with the expression of our deep and respectful sympathy on the death of our late Sovereign, our beloved Queen Victoria.

Her noble life and constant devotion to the welfare of Her subjects commanded our reverence and won our deepest affection.

We look back with pride upon the advancement of science and the progress of the arts that Her glorious Reign has witnessed; and we rejoice that it was our special privilege that it pleased Her to extend to our Society throughout the whole of Her Reign the same gracious patronage that we had received from His Majesty King William the Fourth.

But while we deplore the loss of so beloved a Sovereign, we hail with the most heartfelt satisfaction and congratulation the accession of Your Majesty to the throne of this great Empire, being fully assured that under the auspices of Your Most Gracious Majesty the welfare and prosperity of the Empire and the advancement of science and art will be fully maintained and promoted.

We pray that Your Majesty with Your Royal Consort may, under the blessing of God, be granted both health and happiness and a long and prosperous Reign.

This Address was read by the President at the Annual General Meeting, and the Fellows present signified, by rising in their places, their desire to join in offering the Address to His Majesty.

OBITUARY.

The Council regret that they have to record the loss by death of the following Fellows and Associates during the past year:—

Fellows:—J. S. Ancona.
Thomas Buckney.
Lord Farnham.
James Gill.
J. E. Keeler.
E. J. Lowe.
John McLandsborough.
Horace Pearce.
W. T. Radford.
Sir Josiah Rees.
T. G. Rylands.
C. Piazzi Smyth.
J. H. Young.
Associates:—J. E. Keeler.
Robert Luther.

JOSEPH SUPINO ANCONA, the eldest son of the late Leon Ancona, was born in London on the 4th of September 1819; and died at his residence, Fernleigh, South Norwood, on the 16th of July 1900, in his 81st year, after long suffering from angina pectoris. His early wish was to take Holy Orders and he went to Cambridge with that intention; but his father's loss of fortune about that time made this course impossible and he became an architect and surveyor. He took a keen interest in astronomy, and became a Fellow of this Society on the 10th of March, 1854; but he never published any work on the subject. He married young; his wife died in 1881. They had no family.

THOMAS BUCKNEY was born at Camberwell, London, on the 1st of December 1838. He was connected nearly all his life with the business of Messrs. E. Dent & Co., clock and watch-makers of London, becoming superintendent of the manufacturing department in 1864 and a partner in 1872. A few months later, on the death of his father, he became senior acting partner, and senior partner in 1881. His knowledge of his business was sound and thorough, and extended from watches to the largest turret-clocks. He was the designer of electric contacts for

marine chronometers, and one of his latest and best works was the great clock recently erected at Gloucester Cathedral. He took a special pride in the going of "Big Ben" at the Houses of Parliament, Westminster, which was made by his firm, and in 1887 drew the attention of the Society to the fact that the clock had gone from March 29 to July 6 without any alteration, remaining within 2 sec. of true Greenwich time. From the purely astronomical point of view perhaps his best work was the construction of the Sidereal Standard Clock at Greenwich, in 1871. The clock was to have Airy's escapement (described in Vol. III. of the *Trans. Camb. Phil. Soc.*), and the more delicate parts of this escapement Mr. Buckney made with his own hands. But Airy had ordered a heavy mercurial pendulum, and Mr. Buckney convinced himself from experiments made at the time that a zinc and steel pendulum was preferable, as it would respond to changes of temperature much more readily. The mercury compensation had a sluggish action "due to the more slender parts of the pendulum (the rods and spring) taking up the new temperature very quickly, whilst the bobs, being much more bulky, required a much longer time to do this. . . . Considering the matter, it occurred to me that if we were to eliminate from the compensative action of the zinc and steel pendulums the expansion of the bob, which we could easily do by suspending it at its centre of gravity, and rely entirely on the zinc and steel tubes and rod, matters would be very much improved, as then the compensation would be effected by parts having pretty much the same bulk, and therefore likely to act simultaneously. And so it turned out. . . . In the end I determined to lay the matter before Sir George Airy, and request his sanction to the removal of the mercurial pendulum from the Greenwich clock, and the substitution in its place of a zinc and steel pendulum on the new principle." (*Monthly Notices, R.A.S.*, xlvi., pp. 464–65). That the clock has been a success a glance at any of the subsequent Greenwich volumes will show. In 1880 Mr. Buckney read a paper to this Society suggesting a method of enclosing a clock in an air-tight case, winding it electrically by currents set up by itself. He was a constant attendant at the meetings of the Society (of which he was elected Fellow in May 1880) until recent years. Those who attend the meetings have become accustomed to glance at their watches when the bell rings, knowing that the signal represents accurate Greenwich time. They are indebted for the introduction of this signal to the kindness of Mr. Buckney, who arranged that hourly signals should be sent from Messrs. Dent's to the Society's rooms free of charge; the Society only repaying the rental of the wire charged by the Post Office. His death took place at his residence in London after a short illness on the 1st of February 1900, at the age of sixty-one.

Somerset Henry Maxwell, 10th Baron Farnham, representative Peer of Ireland, J.P., D.L. county Cavan, Lieutenant

88th Regiment (retired), of Farnham, county Cavan, Ireland, died the 22nd of November 1900.

Baron Farnham, son of Richard Thomas Maxwell, son of 6th Baron Farnham and of Charlotte, daughter of Rev. Henry P. Elrington, D.D., Precentor of Ferns, was born the 7th of March 1849, at Newtonbarry, county Wexford, was educated at Harrow, and married Florence Jane, seventh daughter of the 3rd Marquess of Headfort. He had four sons and two daughters. The eldest son having died from the result of an accident immediately after his coming of age, he is succeeded in the title by his second son, the Hon. Arthur Kenlis, born on the 2nd of October, 1879.

As Major Somerset Henry Maxwell his name will be remembered in connection with the land troubles in Ireland in 1881, as he took a prominent part in the resistance made by the landlords against the encroachments of the Land League, and led the expedition fitted out to help Captain Boycott and others on this occasion.

He devoted himself largely to scientific pursuits, more especially to microscopy and astronomy, and had a small but very complete observatory, containing a Grubb 6-inch equatorial and accessories, fitted up at Arley Cottage, on the banks of Lough Sheelan, where he resided until he succeeded to the title in 1896.

In order to ensure the best observing conditions, his observatory was established at some little distance from the dwelling-house, but no considerations of inconvenience or fatigue deterred him from the systematic pursuit of his astronomical labours. He collected a considerable number of double-star measures, and calculated out the orbits himself.

He was anxious to help fellow-workers, and will long and gratefully be remembered by many in the north of Ireland for the prominent part he took in the organising and carrying on of the Ulster Astronomical Society, established in 1890. He was Vice-President of this Society (the President being the Rev. Dr. Hamilton, President of Queen's College, Belfast). He delivered many valuable lectures in connection with this Society.

Later on, other pressing duties having prevented him from devoting so much of his time to this work, the Society was amalgamated with the Belfast Society for the Extension of University Teaching, but there is no doubt that much of the interest in astronomical matters existing at present in Ulster is due to his personal efforts to bring the subject before the public in an attractive and interesting form.

By his will he leaves his natural history collection in trust to the Hon. Judge Boyd and Sir Howard Grubb, F.R.S., and his astronomical observatory to Sir Howard Grubb, F.R.S., and Mr. W. E. Wilson, F.R.S., to be dealt with at their discretion for the benefit of science.

Lord Farnham was elected a Fellow of the Royal Astronomical Society on the 9th of December 1887, and contributed

a short note to the *Monthly Notices* in 1889 (vol. l. p. 34) on "Observations of the Conjunction of *Mars* and *Saturn*."

JAMES GILL was born on the 14th of May 1840, near Port St. Mary, Isle of Man, and though early attracted to the sea and bearing for many years the courtesy title of 'Captain,' he chose rather to train others in navigation and seamanship than to seek a command for himself. To the Mercantile Marine in Liverpool he rendered a very important service by the careful training and instruction he gave to many officers. For many years he was the Principal of the Navigation School at the Sailors' Home, and occupied such a commanding position as a teacher that when the Liverpool Corporation decided to found a school of Nautical Astronomy under their own supervision Mr. Gill was elected to the Head Mastership. In September 1892 the Nautical College was opened with the intention of providing a more thorough and efficient course of instruction than was demanded by the Board of Trade certificates. Mr. Gill loyally recognised the views and intentions of the Corporation, and for eight years he struggled not unsuccessfully against the superficial methods of tuition which had too long obtained in nautical circles. With the view of promoting a sounder study of navigation he published *A Text-Book of Navigation and Nautical Astronomy* (Longmans, 1898), which has attained considerable success.

Mr. Gill was elected a Fellow of this Society in January, 1888, but from a much earlier date he had given assistance to the Liverpool Astronomical Society, and in later times the meetings of this Society were held in apartments in the Nautical College. For some time he was President, and by his influence contributed not a little in keeping this Society together. He died on the 9th of January 1900, leaving a widow and three children.

EDWARD JOSEPH LOWE was the only surviving son of the late Mr. Alfred Lowe, of Highfield House, Nottingham, where he was born on the 11th of November 1825. At the age of fifteen he began an important series of meteorological observations, which were continued down to the time of his removal (in 1882) to Chepstow, Monmouthshire. He published in 1846 "A Treatise on Atmospheric Phenomena," and two years later began to assist the late Professor Baden-Powell, of Oxford, in his work on luminous meteors, and the results of their observations, which extended over a number of years, were communicated to the British Association. Mr. Lowe was elected a Fellow of this Society on the 14th of January 1848, and read his first paper in April 1849, on "Observations of Solar Spots at Mr. Lawson's Observatory, Bath," in which some curious phenomena are described. "The *umbra*, which was of an elongated form, opened in the centre, and so divided it into two parts; it always opened from the lower edge, and was alternately open and closed at intervals of 15^s; this was very sensible, and the experiment

of marking the time which elapsed between the openings was repeated many times." In a footnote is described the "simple and neat" contrivance for registering the positions of spots which was simply a reticule of small squares now known as the *réseau*. Papers which followed were on Meteors and on the Zodiacal Light, which Mr. Lowe observed assiduously. He wrote several very interesting papers on meteors and fireballs in *Recreative Science* and other publications. He observed the eclipse of 1860 at Fuente del Mar, near Santander, making a very complete series of meteorological observations which showed the temperatures at various heights above the ground, amount of cloud, amount of light, &c., during the eclipse (*R.A.S. Memoirs*, vol. xli.). And his activities extended to other branches of science. In the R.S. Catalogue of scientific papers is a list of 46 papers by him (up to 1883) on a great variety of subjects. He invented the dry powder tests for ozone in the atmosphere; he was an ardent naturalist, publishing works on conchology, on British ferns, grasses, and plants. His experiments on the hybridisation of ferns produced some remarkable results, which, however, were not generally accepted as genuine.

He was one of the founders and original Fellows of the Meteorological Society, a Fellow of the Royal, the Geological, the Linnean, and other learned Societies. He married in 1849 Miss Annie Allcock. His death occurred on the 10th of March 1900, at his residence, Shirenewton Hall, Monmouthshire.

John McLandsborough was the eldest son of Andrew McLandsborough, of Kells, in Scotland, who had settled at Otley, in Yorkshire, where his son was born on the 3rd of May 1820. Young McLandsborough was educated in Otley, principally in the grammar school of that town. He was apprenticed to a currier and leather merchant, but after completing his indentures, finding the occupation uncongenial, he obtained employment on the Ordnance Survey, and soon became an expert surveyor. Desiring to be a civil engineer, he spent several years with the late Mr. John Miller, a civil engineer, in Edinburgh, and returning to Yorkshire he commenced practice in Bradford in 1850. His experience in Scotland had been chiefly in connection with the laying out and construction of railways, and he did similar work in his general practice at Bradford. Besides work for other companies, he was instrumental in inducing the Midland Railway to extend their line to Otley and Ilkley, and he was engineer for the line between Keighley and Oxenhope. He was also greatly interested in sanitary engineering, and carried out various waterworks undertakings at Shipley, Horsforth, and Clitheroe, besides drainage works at Burley, Yeadon, and many other places.

When quite a young man Mr. McLandsborough started a Mutual Improvement Society, afterwards merged in a Mechanics' Institute, of which he became a member of the committee of

management. He was always much interested in the institutions of Bradford, and at his death left a fine collection of British minerals and fossils, which he had formed, to the Cartwright Memorial Hall, and about 250 volumes of scientific books to the Central Free Library.

In 1868 he established a meteorological station at Bradford, and commenced a series of daily observations, which are still carried on by Mr. H. A. Johnson, now Mr. McLandsborough's successor in business. He was one of the original members of the Yorkshire Naturalists' Union, and one of the oldest members of the Yorkshire Geological and Polytechnic Society. He was greatly interested in astronomy, and had for many years a good reflecting telescope, by Browning, mounted at his residence at Manningham, near Bradford.

He married Miss Robinson, of Knaresborough, who, with two daughters, survives him. He retired from business in 1882, and continued to reside at Manningham till his death on the 24th of February 1900, in his eightieth year. He was elected a Fellow of the Society on the 14th of March 1873.

Horace Pearce was the youngest son of Mr. Francis Pearce, of Hadley Lodge, Shropshire, and was born on the 21st November 1838. He was for a long period private secretary to the late William Orme Foster, Esq., of Apley Park, Bridgnorth. A man of quiet, retiring habits, he took a great interest in science, being a Fellow of the Geological Society and the Linnæan Society, a member of the Swiss Alpine Club, the Birmingham Naturalist Society, and the Worcestershire Naturalists' Field Club, of the last of which he was president for some years. He was also on the general Committee of the British Association. He had not been in good health for some time, and left England for the South of France in the end of 1899, without, however, deriving much benefit from the change of climate. After a serious illness of about a week, he died, on the 19th February, 1900, at his residence, The Limes, Stourbridge.

He was elected a Fellow of this Society on the 14th of January 1887.

William T. Radford was born at Exeter on the 21st of November 1810. The elder son of Mr. Peter Radford, a physician connected with the Devon and Exeter Hospital, and his wife, formerly a Miss Mackintosh. He was sent to Dr. Carpenter's school at Bristol, and had among his school-fellows James Heywood, Philip Worsley and T. B. Potter. Later he went to Dublin, boarding in the house of James Martineau and studying at Trinity College, where he took the degrees of M.B. and M.D. He walked the hospitals but never practised as a doctor. In 1839 he and his mother (his father having died when he was a child) came to reside with his younger brother at Sidmount, Sidmouth, which continued to be his home until he died on the

19th of May 1900. He devoted himself chiefly to the study of science (especially meteorology) and art, spending some months of each year in London and travelling a great deal on the Continent; he visited most of the capitals of Europe and nearly all the principal cathedrals. When at home he devoted much time to microscopic studies and also worked a great deal with his telescopes, particularly one by Steinheil, $4\frac{2}{10}$ ins. diameter, with which he resolved many double stars, but no record of the results of his observations can be found. He collected an extensive and valuable library, which was particularly rich in illustrated works, and in books of reference on most subjects. He also had a number of engravings, art photographs, cameos, bronzes, &c. About thirty years ago he began giving away spectacles to the poor lace workers of the district, carefully testing their sight; this charity gradually extended to others who were in need until, when shortly before his death he was obliged by failing health to give up seeing any more applicants, he had given away more than 32,000 pairs. He was unmarried. He retained his faculties and his interest in scientific, artistic and general literature until a very short time before his death, which was sudden at last from heart failure.

He was elected a Fellow of the Society on the 13th of January 1865.

At the beginning of 1900 there were four names in our list of Fellows with date of election prior to 1850—viz. James Glaisher (1841), Sir Josiah Rees (1844), C. Piazzi Smyth (1846), E. J. Lowe (1848). Of these we have to deplore the loss by death of the second, third, and fourth.

Sir Josiah Rees was the son of the late Mr. J. Rees and was born in 1821. He was called to the Bar at the Middle Temple in 1851 and was a revising barrister on the South Wales and Chester circuit from 1865 to 1877. In 1878 he was appointed Chief Justice of Bermuda, and he was also judge of the Vice-Admiralty Court of Bermuda and President of the Legislative Council. He was knighted in 1891. In 1876 he married Eliza, daughter of Mr. J. Acock, of Cheltenham; she died in 1887. The death of Sir Josiah Rees occurred in November 1899, but the news did not reach us until after the close of the year. He was elected a Fellow of this Society on the 10th of May 1844, being proposed by the late Admiral Smyth.

Thomas Glazebrook Rylands was born at Warrington on the 24th of May 1818, and died at his residence, Highfields, Thelwall, Cheshire, on the 14th of February 1900. He was a wire manufacturer, ironmaster, &c., but found time to develop an interest in many sciences—entomology, botany, geology, mineralogy, zoology, and, later, astronomy. He was a regular attendant at the meetings of the British Association. He did not publish any astronomical work, though for a number of

years he constantly used his equatorial and transit. Several years before his death he vested these instruments in trustees for the benefit of the city of Liverpool; they were originally mounted at the Nautical Academy in Colquitt Street, and when the Corporation erected a Technical Institute they were transferred to suitable mountings on the roof of that building.

In 1893 Mr. Rylands published privately a handsome volume entitled *The Geography of Ptolemy Elucidated* (University Press, Dublin), in which by careful investigations he seeks to establish and demonstrate, by beautiful diagrams, a higher degree of accuracy in Ptolemy's writings than he had been previously credited with. A copy of the work is in the Library of the Society, presented by the author.

Mr. Rylands bequeathed to the University Library, Liverpool, a large number of books containing MSS. and early printed works, of which a Catalogue has just been printed at the Liverpool University Press. In the Preface to the Catalogue Principal Dale says:—"The collection is the most valuable that we have yet received in any single gift."

He was a good Greek and Latin scholar and an able mathematician, and possessed a fair knowledge of architecture, heraldry and ancient geography. He was a Justice of the Peace for Warrington and Mayor of Warrington 1858–59.

He was married twice, and leaves a widow, two sons and a daughter.

He was elected a Fellow of this Society on the 12th of January 1866.

The father of the late Charles Piazzi Smyth, the well-known Admiral Smyth, spent the early years of his married life on the Mediterranean Station. At Palermo he made the acquaintance of the venerable Italian astronomer, Giuseppe Piazzi. The Admiral and his wife (Annarella, daughter of T. Warington, Esq., of Naples), who is still remembered as "a lady of great ability and rare accomplishments," were so much interested in the studies of their distinguished friend that they named their second son, who was born at Naples on the 3rd of January 1819, Charles Piazzi Smyth. The celebrated astronomer acted as godfather, and at the christening expressed the desire that the child might become an astronomer. When the boy was about eleven years old his father, who had settled at Bedford, bought what was then considered a powerful telescope, and erected the well-known Bedford Observatory. One can easily imagine with what enthusiasm the Admiral pointed out the various constellations to his clever children and taught them the rudiments of astronomy, for, besides Charles, there were two sons and several daughters. The eldest son, Sir Warington Smyth, became Professor of Mineralogy at the Royal School of Mines. The third son is General Sir Henry Smyth. One of the daughters married Sir William Flower, late Director of the Natural

History Museum, South Kensington; another, who is mentioned as the special companion of the Admiral, died before her parents; while yet another daughter is Mrs. Baden-Powell, mother of the hero of Mafeking.

At the age of ten years we find Piazzi Smyth a pupil at the Bedford Grammar School, which he left when he was sixteen and went to the Cape as assistant to Mr. (afterwards Sir Thomas) Maclear. The way in which he at once assisted Maclear in observing Halley's Comet, and, in particular, his characteristic drawings of the comet published in *R.A.S. Memoirs*, vol. x., show how much he had profited by his home training in astronomy and astronomical drawing. In 1843 he made a series of observations of the great Comet of that year, extending from 5th March to 19th April with a $3\frac{1}{2}$-inch portable telescope, which seems to have been the largest instrument then available at the Cape for extra-meridional observations. He also depicted in oils the appearance of the great Comet as seen in the late evening twilight, with its slender and somewhat plumed tail stretching far up into the sky.

Apart from sharing in the routine work of the Observatory, he took a particularly active part in the Verification and Extension of La Caille's Arc of Meridian, which had been preceded by an interesting triangulation for connecting La Caille's Observatory, the modern Observatory, and Sir John Herschel's large Reflecting Telescope. He also shared in the measurement of the Zwartland Base, which lasted from 30th October 1840 until 5th April 1841, and which required the co-operation of no less than twenty-six persons. But several of these seem to have been frequently prostrated by sickness due to exposure to violent winds alternating with great heat.

In the triangulation Piazzi Smyth seems to have had a full share of work at the loftier stations, including Kamies-Sector Berg, 5141 feet high; Winter Berg, 6818 feet, occupied from July 9 to October 10, 1844, and mentioned by Maclear as "a difficult snow-capped mountain in the winter season"; and, lastly, Sneeuw Kop, 5211 feet, occupied from November 22, 1844, to July 21, 1845.

Piazzi Smyth then returned to the Observatory, preparatory to leaving the Cape for Edinburgh, where he had been appointed successor to Henderson as Astronomer Royal for Scotland and Professor of Practical Astronomy in the University of Edinburgh. But he delayed his departure for a time in order to facilitate the extension of the triangulation to Cape L'Agulhas, and did not sail for England until the 22nd October 1845. He carried with him the best wishes of Maclear, who speaks of him as "experienced in the details of meridian work, and unflinching in hardships," and adds that "he had a happy talent, with the assistance of his pencil, in conciliating the inhabitants, . . . and his robust constitution fitted him for taking an active share in the triangulation."

On arriving in Edinburgh he made it his first duty to complete the reductions of the observations accumulated by his predecessor, Thomas Henderson. In this work he was ably seconded by the late Alexander Wallace, who held the post of first assistant from the time of Henderson's appointment in 1834 until 1880. The collected results of these observations were eventually published in *Edinburgh Observations*, vols. xiv. and xv. When Piazzi Smyth commenced a further series of observations with the beautiful transit instrument used by his predecessor, he was at once confronted by a serious difficulty which had already been recognised by Henderson. This was the great susceptibility of the instrument to changes of temperature. After much skilful and patient observation, the disturbances were eventually traced in great part to the expansion and contraction of the regulating screws attached to the Y's. The adjustable Y's were discarded in 1848, and the stability of the instrument was thereby much increased. In 1851 Professor Smyth proceeded to Norway in company with Dr. T. R. Robinson, of Armagh, to observe a total eclipse of the Sun. Owing to clouds the eclipse itself was not seen; but, thanks to very complete preparations, Piazzi Smyth was able to make a number of sketches showing the various effects of light, shade, and colour incidental to the passage of the dark shadow of the Moon. Two of these sketches were reproduced in chromo-lithography in *Edinburgh Observations*, vol. xii., and Sir Robert Ball, in the *Story of the Sun*, also makes use of the Professor's unique sketches and verbal description to convey a vivid impression of the sudden darkness and the weird bordering of distant light, which are characteristic features even when the actual eclipse is hidden by clouds.

In 1856 Professor Smyth married Miss Jessie Duncan, who throughout the long period of forty years of their married life acted as his enthusiastic and indefatigable helpmate in all his work and accompanied him on all his journeys. In the same year Piazzi Smyth was in a position to carry out a long-cherished plan, viz. to undertake an astronomical expedition to the Peak of Teneriffe in search of Newton's "most serene and quiet Air, such as may perhaps be found on the tops of the highest Mountains above the grosser clouds." He fixed on this particular mountain on account of its being readily accessible in a fairly low latitude, and easy of ascent. In May 1856 the Admiralty entrusted him with a scientific mission to the Peak, placing 500*l.* at his disposal. At the same time Robert Stephenson, M.P., invited him to make use of his yacht "Titania" of 140 tons, for the whole time of the expedition. Preparations were pushed forward so eagerly that already in June Professor and Mrs. Smyth embarked in the "Titania." The chief instrument taken out was a beautiful and very complete equatorial of $7\frac{1}{4}$ inches aperture by T. Cooke & Sons, lent by Mr. Pattinson of Newcastle-upon-Tyne. The first station occupied in Teneriffe was the summit of Guajara at a height of 8900 feet on the

southern wall of the "crater of elevation," distant some five miles from the Peak itself. The Professor and his wife remained at Guajara from 14th July till 20th August. The experiences of camp life gained while engaged on the Cape geodetic operations here stood the party in good stead; hence, with the help of three "isleños" and a couple of men from the yacht a substantial temporary observatory was soon rigged up and the work of the expedition begun. From the very first Piazzi Smyth was delighted with the sharp definition and perfect steadiness of the stellar discs and their surrounding diffraction rings as shown in the 3·6-inch Sheepshanks equatorial from the Edinburgh Observatory; this in itself went far to prove that the "most serene and quiet air" did really exist "above the grosser clouds." A series of measures of the Moon's radiant heat was rewarded by an encouraging degree of success, confirming as they did the earlier experiments of Melloni by showing that the heat received from the full Moon was not altogether inappreciable. His examination of the solar spectrum at various hours of the day was conducted in such manner as to turn to the best advantage the unique conditions under which he worked. It was clearly recognised that the Fraunhofer lines were partly of solar and partly of terrestrial origin. The rapid increase in the number and blackness of the atmospheric lines as the Sun approached the horizon was carefully depicted in a series of drawings of the solar spectrum with the Sun at zenith distances ranging from 12° to 91°·1. The meteorological features of the region above the clouds were perseveringly studied with the hygrometer and black-bulb thermometer. Drawings were made of the lower cloud strata, while the "battle of the clouds" that heralded the breaking up of the summer season on the Peak was described with singular felicity. To bring out the diurnal phenomena more clearly recourse was had to the method of term-days introduced by Sir John Herschel. These observations were in part made simultaneously on board the yacht lying in Vera Cruz roads and on the summit of Guajara.

Though on the whole Piazzi Smyth had much reason to be satisfied with the work accomplished on Guajara, yet the dust-haze which from time to time impaired the clearness of the atmosphere made him wish to test the atmospheric conditions at a yet higher level. Accordingly on the 21st of August a move was made to Alta Vista, 10,700 feet above sea-level, where, after many difficulties had been overcome, the Pattinson equatorial was successfully installed on the 3rd of September at the highest point accessible to mules. The next afternoon the companion to *Antares* was seen twenty minutes before sunset, with powers of 160 to 500, both with direct and transparent-reflector eyepiece. At night the instrument was found to perform admirably on close double stars: concerning γ_2 *Andromedæ* the Professor writes "Duplicity of B, C at once apparent, powers 350 to 800; C is smaller than B; they are seen as two separate stars with a

dark line between them, though at the same time they somewhat compress each other's discs." *Jupiter*, then in good position, presented the magnificent spectacle so skilfully depicted in the well-known drawings published in *Edinburgh Observations*, vol. xii., and in *Phil. Trans.* for 1858. The many-sided genius of the Professor was strongly brought out on an excursion to the summit of the Peak. He gives a most interesting description of the various zones of lava streams, and fully accounts for the presence of a population of birds and insects in the terminal crater by the moisture due to steam given out by the volcano. The famed ice-cavern, from which the camp obtained their supply of water, was explored and described. The remarkable instance of lateral refraction recorded by Humboldt, which had been a puzzle to scientists for half a century, is discussed, and attention drawn suggestively to the fact that the observation was made in the neighbourhood of the well-known "narix" or blow-hole, where Smyth himself found the barometric readings to be altogether abnormal. Unfortunately autumn burst in on the observing party much earlier than was expected, and forced upon Piazzi Smyth the conviction that at a high level the seasons occur much more in accordance with the solstices than is the case at lower elevations. Accordingly this notable "Astronomer's Experiment" was concluded on the 19th of September. The results of the expedition were published in a *Report on the Teneriffe Astronomical Experiment of* 1856, *addressed to the Lords Commissioners of the Admiralty*, 4to, London and Edinburgh, 1858; and, with some omissions, in the *Phil. Trans.* for the same year; while much of the detail and certain enlarged photographs are included in vol. xii. of the *Edinburgh Observations*. These valuable photographs show the difference of the actinic transparency of the air at a height of 10,700 feet and at sea-level. In *Teneriffe, an Astronomer's Experiment: or, Specialities of a Residence above the Clouds*, 8vo, London, 1858, the general reader with astronomical tastes will find one of the most fascinating volumes ever written. Its interest and permanent value are much enhanced by the score of photo-stereographs with which it is illustrated.

A voyage to Russia by way of the Baltic was undertaken in 1859, an account of which is given in *Three Cities in Russia*, 2 vols. 8vo., London, 1862. Here, again, an additional charm is lent to the narrative by Smyth's own characteristic illustrations. The astronomer's interest in these volumes naturally centres in the description of the great Observatory at Pulkowa. The venerable designer of that famous establishment, W. von Struve, was unfortunately absent, but the honours of the place were most hospitably done by his son Otto and the distinguished staff of Associate Astronomers.

Our Inheritance in the Great Pyramid, a volume published in 1864, shows how much Piazzi Smyth's thoughts were at this time occupied with that wonderful monument; and it is there-

fore not surprising that we find Professor and Mrs. Smyth settled at Gizeh in the beginning of 1865. Here he measured the Great Pyramid as to its orientation, the size and slope of its great passages, and the dimensions of its inner chambers. The greatest care and accuracy were bestowed in finding the dimensions and cubic content of the sarcophagus in the King's Chamber. These investigations are discussed with much detail and illustrated by many plates in *Edinburgh Observations*, vol xiii., a volume which will always be regarded as a standard work of reference on the metrology of the Great Pyramid. The value of these measurements, and the skill with which they were made, were fully recognised by the Royal Society of Edinburgh, who awarded the Keith Prize to Professor Smyth in 1867. So much public interest had been aroused by these investigations that Piazzi Smyth was induced to issue a work of three volumes in a more popular form entitled *Life and Work at the Great Pyramid*, which was followed in 1868 by yet another volume *On the Antiquity of Intellectual Man, from a Practical and Astronomical point of View.* It is much to be regretted that these volumes are largely interspersed with mystical speculations to the great prejudice of their scientific value. Unfortunately this tendency displayed in his works on the Great Pyramid led to controversies with the Council of the Royal Society of London, which culminated in Piazzi Smyth's withdrawal from the Society in 1874.

Shortly afterwards the indefatigable Professor engrossed himself with Spectroscopy. He worked at the Solar Spectrum, the Spectra of Luminous Gases, of the Aurora, and of the Rain-band. The occasion of a visit to Palermo in the spring of 1872 had been utilised in making spectroscopic observations of the Zodiacal Light, the spectrum of which he found to resemble closely that of very feeble twilight (*Monthly Notices*, vol. xxxii. p. 277). Finding it practically impossible to study the Solar Spectrum to advantage in the smoky atmosphere of Edinburgh, we again see Piazzi Smyth in 1877 transport his instruments to a sunnier climate, which this time he found in Portugal. Here he addressed himself to an examination of the red end of the Solar Spectrum, and certainly made notable progress in the resolution of the great bands in that region into their constituent lines. His results were communicated to the Royal Society of Edinburgh and published in the twenty-ninth volume of their *Transactions*; and in 1 80 he was awarded the Makdougall-Brisbane Prize for these researches. Four years later we see him start for Madeira, again in quest of sunshine. With improved apparatus, including a Rutherfurd grating with 17,296 lines to the inch, he succeeded in completely resolving many of the more difficult groups of lines in the visual spectrum of sunlight. The results of this excursion were given to the world in a handsome volume entitled *Madeira Spectroscopic*, 4to, Edinburgh, 1882. Piazzi Smyth's most detailed survey of the Solar Spectrum was accom-

plished in Winchester in the summer of 1884. The object of this work was partly to ascertain whether the great volcanic eruptions of 1883 had in any appreciable degree affected the absorptive power of the Earth's atmosphere. On this occasion the apparatus used was rendered more perfect by the addition of a magnificent Rowland grating. The outcome of this interesting survey appeared in a memoir, illustrated by sixty-one coloured plates, entitled "The Visual, Grating and Glass-lens Solar Spectrum (in 1884)," contained in vol. xxxii. Part II. of the *Edinburgh Transactions*.

In connection with his reseaches in Solar Spectroscopy he carried on an extensive series of laboratory investigations, in the course of which, in conjunction with Professor Alexander Herschel, he discovered the rhythmical relation between the chief lines of carbonic oxide gas. These remarks are set forth in the following papers : "End-on Illumination in Private Spectroscopy, and its Applications to both Blow-pipe Flames and Electric Illumined Gas-vacuum Tubes," 1879; "Carbon and Carbo-Hydrogen spectroscoped and spectrometed in 1879," and "Micrometrical Measures of Gaseous Spectra under High Dispersion," 1886.

In the hours of relaxation from his purely scientific labours Piazzi Smyth turned his inventive genius, with the same eagerness that characterised all he did, to the field of mechanical invention. A problem which long attracted his attention was the construction of a "free-revolver stand" on the principle of the gyroscope, for the steady support of scientific instruments at sea. An apparatus of this kind was tried with considerable success on the voyage to Teneriffe. Unfortunately the spinning motion had to be imparted by means of a rope pulled from time to time by the all-too-willing sailors : an important axle gave way just when the experiment seemed most promising. It is much to be regretted that this important invention has never been further developed. The excitement of the Crimean War turned the Professor's thoughts to the construction of a portable distance measurer. On his Russian journey he was alike surprised and delighted to find that a Russian astronomer had hit upon identically the same construction at the same exciting epoch. In 1852 an ingenious system was devised of signalling the time from the observatory on Calton Hill by means of a time-ball. This was supplemented in 1861 by a time-gun at Edinburgh Castle and the establishment of sympathetic clocks in various parts of the city. Eventually Dundee was included in the circuit. In this work he was ably assisted by James Ritchie & Son, the well-known Edinburgh clockmakers. To meteorology he made many important contributions, amongst which may be mentioned his discussion of the readings of the rock thermometers established on Calton Hill in 1837, in their relation to the sun spot period and the mean temperature of Scotland.

In 1888 Piazzi Smyth resigned his position as Director of the

Observatory and Professor in the University which he had held for forty-three years, and with his wife retired to a country house near Ripon, which was named Clova in remembrance of a place in Aberdeenshire where Mrs. Smyth had spent part of her life. Here he continued his work with unflagging zeal, photographing the Solar Spectrum on a large scale with the help of the Rowland grating; he also secured a beautiful series of photographs of typical cloud formations. After the Professor's death the negatives of these latter photographs were generously presented to the Edinburgh Royal Observatory by Mr. W. B. Dunlop of Edinburgh.

In 1896 Mrs. Smyth, the faithful and indefatigable sharer of all his labours, succumbed to a long and painful illness. After her death the Professor led even a more retired life than before, though still occupied with astronomical problems.

He died at Clova on the 21st of February 1900, and was buried beside his wife in the churchyard of Sharow, a parish some two miles distant from Clova.

On glancing back at Professor Piazzi Smyth's life, thus imperfectly sketched, one cannot but admire his indomitable energy and activity and the great versatility of his mind. He was a keen observer of Nature, and thanks to his skill alike with pen and pencil he succeeded in interesting a world-wide circle of readers in the objects in which he himself was interested. His contributions to sidereal astronomy, to mountain astronomy—to which he gave an impetus that cannot be over-estimated—and especially to spectroscopy will always secure him a high place amongst the scientific workers of the Victorian era. Though he was of a retiring disposition, those who came in contact with Piazzi Smyth were attracted by the gentle amiability of his manner and by his readiness to impart full particulars of the investigation on which he happened to be engaged

Professor Smyth was a Corresponding Member of the Academies of Science of Munich and Palermo, and a Fellow of the Royal Societies of London and Edinburgh. He received the honorary degree of LL.D. from the University of Edinburgh, and was elected Fellow of this Society as far back as 1846.

R. C.

James Henry Young, a son of the late Captain J. H. Young of Jersey, was born at Gorey, Jersey, on the 23rd of January 1858. He was educated at the Victoria College, Jersey, and at the age of 18 entered the Civil Service in the Office of Works, in which appointment he continued up to the time of his sudden death on the 24th of September, 1900. He married in 1879 Miss Mildred E. C. Jerrold (a granddaughter of Douglas Jerrold), and leaves five children. He graduated as B.Sc. at the London University in 1892. He was accustomed to public lecturing, some of the titles chosen being "Star-myths and what has become of them," "Sun-spots," "The Earth's Future," "Sixty

Years of Astronomy," &c., &c. He was elected a Fellow of this Society on the 12th of May, 1893.

The two Associates whose loss the Society has suffered during the last year were near the two ends of the illustrious list. Robert Luther was one of the oldest, and Keeler one of the youngest. Keeler might well have been elected earlier on his merits, but there was a difficult preliminary question of procedure to be settled —viz. whether a Fellow of the Society was eligible as an Associate. (For Keeler was one of several eminent American astronomers whom we are proud to have as actual Fellows, having joined the Society on the 14th of March 1890.) In 1898 the Council decided this question in the affirmative, and forthwith Barnard, Burnham, and Keeler were elected Associates on the 9th of December 1898. The first two were already also medallists of the Society; and there can be little doubt that only his premature and lamented death robbed Keeler of a similar honour, for his work was brilliant in quality, and he was an untiring worker. For the following particulars of his life the Council is chiefly indebted to the sympathetic and able notice by his successor in the directorate of the Lick Observatory, Professor W. W. Campbell (*Astrophysical Journal*, November 1900), to which reference should be made for a fuller account.

James Edward Keeler was born in La Salle, Illinois, on the 10th of September 1857, of a long line of New England ancestry. The family removed to Mayport, Florida, in 1869, and here Keeler not only prepared himself by private study for the university, but began his astronomical work. He drew the planets at a 2-inch telescope, and constructed a transit circle, rough in appearance, but, no doubt, capable of giving good results in the hands of its skilful maker. The circle was of wood, with a paper graduated scale, and the clock was a "small kitchen affair, and kept execrable time. It had no second hand. . . . A tall pine tree nearly on the meridian served for purposes of collimation" (*Pub. Ast. Soc. Pacific*, xii. p. 169).

Keeler entered Johns Hopkins University, Baltimore, in 1877, and graduated in 1881; but some weeks before taking his degree he was appointed assistant to Langley at the Allegheny Observatory. Langley was just starting for the summit of Mount Whitney to make his determination of the value of the "Solar Constant," and Keeler accompanied him on the expedition. His work for the next two years was concerned with the results obtained. He then spent a year in Europe, attending lectures in Heidelberg and Berlin on physics and mathematics, returning to the Allegheny Observatory in the summer of 1884 to help Professor Langley with his researches on the infra-red portion of the spectrum.

Early in 1886 Keeler was appointed assistant to the Lick Trustees, and, reaching Mount Hamilton on the 25th of April, he established the time-service more than two years before the

Observatory was completed and transferred to the University of California. On this completion in 1888 he was appointed astronomer in charge of the spectroscopic work, in addition to the time-service. In the three years which followed he produced some brilliant results, especially those relating to the motion of the nebulæ in the line of sight. Taking advantage of the fact that, other things being equal, high dispersion does not weaken the brightness of a monochromatic line, Keeler used a grating for these faint objects, and the wave-lengths were measured in the third and fourth orders of spectrum. There was no available comparison line for the line measured (the principal nebular line at λ 5007·05), but Keeler ingeniously deduced the wave-length of this line from observations on the *Orion* nebula, which he independently found (from the β line of hydrogen) to be receding from the solar system at about 18 km. per second. The velocities of thirteen planetary nebulæ were thus found to vary from -65 to $+48$ km. per second, and are accordingly of the same order of magnitude as those of the stars.

In 1891 Keeler was summoned to succeed Langley at the Allegheny Observatory, and here he continued his spectroscopic successes. His main piece of work there, on the spectra of Secchi's third type stars, remains still unpublished; but everyone will remember his wonderful photograph of the spectra of *Saturn* and his rings, which first directly demonstrated the meteoric character of the ring, inferred theoretically by Clerk-Maxwell many years ago.

In 1898 Keeler was again called upon to return as Director to an observatory at which he had previously been an assistant—this time to the Lick Observatory. The tragedy of his early death is enhanced by the warm words of recognition of what he did in his few years of office, spoken by Professor Campbell in the name of the whole staff. "I but faintly reflect the views of every member of the staff," he writes, "and, indeed, of all who have been interested in the work of the Lick Observatory, when I say that his administration was completely successful. He cherished and promoted ideal conditions in this ideal place. He made a success of his own work in a splendidly scientific manner, and he saw to it that everyone had every possible opportunity to do the same. No member of the staff was asked to sacrifice his individuality in the slightest degree. Nor were demands made for immediate results. The peace of mind of the investigator, so absolutely required for complete success, was full and undisturbed."

The work he chose as his own on his return to Mount Hamilton was not spectroscopic as before, but the photography of nebulæ with the Crossley reflector. It was one of the strongest traits in Keeler's character that he was ready to adapt himself at once to new conditions; and in the rather frequent changes of his all too short working life this capacity was of the greatest value to him. "He comprehended the possibilities and limitations of his situation," writes Professor Campbell, "and adapted himself to

them." Thus when he returned to Allegheny as Director, his spectroscopic researches were largely confined to the orange, yellow and green regions of the spectrum, since they would be less strongly affected by the smoky sky for which that vicinity is famous; and yet by attending to such limitations he managed to produce his beautiful photograph of the spectrum of *Saturn*. When he returned to the Lick Observatory he found the spectroscopic work in the able hands of Professor Campbell, and himself therefore undertook the solution of a troublesome question —or rather what had been a troublesome question before he came. The Crossley reflector, the 3-foot reflector with which Dr. Common showed the way in the photography of nebulæ, afterwards acquired by Mr. Crossley of Halifax, had been presented by him to the Lick Observatory. The assistants told off to work with it failed to secure any good results, and blamed the instrument as antiquated and almost worthless. The new Director himself undertook to see what was wrong. He found a good deal capable of improvement and spent five months making one change after another. His account of this work (*Astrophysical Journal*, June 1900) is a model of clearness and completeness. At the end of this time the instrument immediately produced pictures of marvellous beauty in abundance. Keeler set himself to photograph the whole of Herschel's nebulæ, and had done more than half at his death. The plates record incidentally a large number of new nebulæ, and he estimated that the number to be discovered by the Crossley reflector could not be less than 120,000. The important fact that more than half the nebulæ turn out to be spiral in form was established from these plates, and has an important bearing on the theory of the cosmogony.

His death was very sudden. He became weak in health in the summer of 1900, being unable to throw off a cold contracted in June, and left the observatory on the 30th of July, with no anxiety, to secure medical treatment and take a holiday. Increasing difficulty in breathing led him to seek skilled assistance in San Francisco on the 10th of August; the dangerous condition of his heart, which had been weak for some years, was realised on the next day; and on the 12th of August a stroke of apoplexy proved fatal.

He had the Rumford Medal of the American Academy in 1898, and the Henry Draper Medal in 1899. He was an editor of *Astronomy and Astrophysics*, and subsequently of the *Astrophysical Journal*, and a member of many learned Societies. He was, as above recorded, both a Fellow and an Associate of this Society. He married on the 16th of June, 1891, Miss Cora S. Matthews, at Oakley Plantation, Louisiana, and leaves two children.

H. H. T.

By the death of Dr. ROBERT LUTHER the Society loses one of its oldest Associates, and one who occupied a noteworthy position in the list. There are still three illustrious veterans who were elected

Associates on the 12th of May 1848 (Faye, Galle, O. Struve), but the next now in sequence form another trio with date the 11th of May 1866 (Auwers, Foerster, Safford). The first three are all that remain of a group of twenty-one, elected when the Council first undertook the suggestion of names, which had been previously left to individual Fellows; and of twenty-one further elections in the years 1849 to 1865 (none, however, being made in the six years 1856 to 1861) Robert Luther was the sole survivor, the date of his election being the 9th of June 1854. He was a marvellous discoverer of minor planets in the days when photography had not made the discovery easy. His first discovery was No. 17, made in 1852; and though Graham, of Cambridge (who discovered No. 9 in 1848), outlives him, the fact that Luther also discovered *Glauke*, No. 288, in 1890 makes his record quite unique.

Carl Theodor Robert Luther was born at Schweidnitz on the 16th of April, 1822. His father, F. H. A. August Luther, had distinguished himself in the war of 1813–15, gaining officer's rank and the Iron Cross, but had lost his right arm in the attack on St. Amand in June 1815. He learnt to write with his left hand, and obtained a civil appointment, marrying in 1818; but his health had been shattered by his wound, and he was pensioned in 1823. From that time to his death in 1844 his life was one long illness, in which he was devotedly nursed by his wife, who died in 1853. Their only son, Robert, born in 1822, went to the Gymnasium at Schweidnitz, 1831 to 1841; thence to the University of Breslau, and (in 1843) to that of Berlin. Here he remained after his father's death in 1844, studying under Encke, Dove, and others, taking a share in computations for the *Astronomisches Jahrbuch* for 1849, &c., doing some laborious work under Encke on cometary orbits, and taking a part in the Berlin observations from 1847 onwards. When Brünnow left the Bilk-Düsseldorf Observatory for Berlin in 1851, Luther was appointed, on the strength of many recommendations, his successor at Düsseldorf. Here, for twenty-six years, his only instrument was a 6-foot refractor, with ring-micrometer; and, on the advice of Argelander and Hülsmann, he used this instrument for planetary observations, and thus was in regular communication with the Bonn, Berlin, Hamburg, Vienna, and other Observatories. He discovered his first small planet on the 17th of April 1852, which was named *Thetis* by Argelander, and the discovery so delighted the people of Düsseldorf that they honoured the event with a public banquet in the *Tonhalle*, or Concert Hall, at which Argelander assisted. Luther was, moreover, so much encouraged by this success, and the recognition of it, that he refused to leave Düsseldorf for better appointments elsewhere, and the little Observatory has to thank him for crediting it with twenty-four planetary discoveries in all, besides three in which he failed to secure priority. In the years 1852 to 1861 he was

seven times awarded the Lalande prize for different discoveries. His small salary was increased by the town after his fourth discovery, and again in 1860; in 1861 the State also supplemented it. He was twice decorated by the King, in 1855 and 1863; and many other honours were conferred upon him by learned societies. He was elected an Associate of this Society in 1854.

In the years 1854 to 1857 he prepared the Berlin star-chart for 0^h, containing 4302 stars; and he was no less diligent in computation than in observation. It was due to his computations that Goldschmidt rediscovered the planet *Melete*, which had been thought to be *Daphne*; and in the *Berliner Jahrbuch* for 1865 it is recorded how Luther had rediscovered and reobserved the planets *Calypso* and *Daphne*, which had not been observed for four and six years respectively. Among his numerous calculations may be specially mentioned those of the orbits of *Hebe* (1847–1900), *Parthenope* (1850–1901), *Melete* (1857–1901), *Danaë* (1861–1900), *Glauke* (1890–1901). He worked with the greatest assiduity all his life, and it was specially appropriate that he was elected Associate of the K. Leopoldino-Karolin. Deutsche Akad. der Naturforscher in Halle," whose motto is *Nunquam otiosus*, for Luther only took four holidays from 1852 till his death.

He married in 1859 Fräulein Caroline Märcker, who was born at Essen in 1823 and still survives. Their only son, Alexander Wilhelm Luther, born in 1860, became an Assistant in the Düsseldorf Observatory in 1892, and succeeded his father as Director in 1900.

Robert Luther died on the 15th day of February 1900, after an illness of only three days. H. H. T.

Proceedings of Observatories.

The following reports of the proceedings of Observatories during the past year have been received from the Directors of the several Observatories, who are alone responsible for the same.

Royal Observatory, Greenwich.

Transit Circle.—10,438 observations of transits and 9595 of zenith distances were made in 1900, about 2000 of these observations having been made below pole. The total number of stars observed is about 4500, some 1400 of these being within 10° of the pole.

By the end of this, the fourth year of observation, all stars that are intended to form part of the third Ten Year Catalogue have been observed at least once, with six exceptions, all lying outside the circumpolar zone that forms the principal subject of observation. To complete five observations for every star within two degrees of the pole, with at least two observations on each side of the pole, only two observations are required.

The Sun was observed 182 times with the transit circle, its horizontal diameter 146 times, and its vertical diameter 154 times.

The Moon was observed 123 times; the mean error in R.A. of Hansen's Lunar Tables with Newcomb's corrections is $-0^{s}\cdot129$. The errors since 1883, when Newcomb's corrections to Hansen's tables were introduced into the *Nautical Almanac*, are as follow:—

	s		s		s
1883	+0·031	1889	+0·010	1895	−0·066
1884	+0·018	1890	+0·020	1896	−0·088
1885	+0·024	1891	+0·079	1897	−0·154
1886	+0·029	1892	+0·083	1898	−0·160
1887	+0·059	1893	+0·034	1899	−0·101
1888	+0·090	1894	−0·016	1900	−0·129

The planets have been observed as usual, and amongst them *Eros*, of which small planet ten observations have been secured since October. The R—D discordance agrees closely with that

found in 1899; in both years it is slightly larger than it was in 1897 and 1898, the correction to the D observation being:—

$$+0''\cdot08 + 0''\cdot22 \sin ZD \text{ in } 1899$$
$$+0''\cdot09 + 0''\cdot32 \sin ZD \text{ in } 1900$$

The second Ten Year Catalogue of 6892 stars for 1890 has been printed, and some advance copies have been received. The special object of the catalogue was the re-observation of the stars contained in Groombridge's Circumpolar Catalogue (1810), as well as of fundamental stars, and it thus provides material for a discussion of the co-latitude and the refraction, as well as for a determination of the proper motions of Groombridge's stars, which has been made provisionally for 174 stars having a proper motion of at least 0''·1 in R.A. or N.P.D. As a preliminary step in the determination of the proper motions of all the Groombridge stars—4000 in number—a new reduction of Groombridge's observations has been undertaken, and is steadily progressing. The observations made in 1806 and 1807 are completely reduced to 1810·0, and the observations of 1808 will soon be completed. The clock star and azimuth star places have been derived from Professor Newcomb's fundamental catalogue, as also the places of stars used for polar points. There are 15 double transits of *Polaris* which give a mean place practically identical with that derived from Newcomb's catalogue; and the places of the other close polars depending on Groombridge's observations of *Polaris* made on the same day, agree well on the whole with Newcomb's catalogue places. As it was apparent that the observations of the standard polars were not sufficiently numerous to give azimuth errors for every day's observations, a supplementary list of stars whose places depend on observations on days on which some of the standard polars were also observed was drawn up, and these stars where necessary have been used for the determination of azimuth errors. In this way the Right Ascensions are made as far as possible perfectly fundamental. Nearly the whole of the stars within 10° of the pole were observed in 1807, and the new places are not very different from the original catalogue places, with one notable exception—viz. Groombridge 1119. Beyond 10° from the pole the effect of the revision is to reduce the discordances between Groombridge and Newcomb's fundamental system to a small fraction of their original amount. Groombridge's instrument being reversible, the results of the two positions have been kept separate, and comparison shows a very close agreement between the two.

The north polar distances are strictly differential, and the polar points are on the average derived from six or more fundamental stars, so that the zero point is well determined. From comparison between the old and new places it is found that the corrections to the former practically agree with those given by

Boss; the results in both positions of the instrument are very fairly accordant.

The Altazimuth.—This reversible instrument has been used in all four positions in the meridian and also occasionally out of the meridian. During the year 1629 transits and 1504 zenith distances have been observed in the meridian, and 68 azimuths and zenith distances in other azimuths. The Moon was observed 27 times in right ascension and zenith distance on the meridian and twice in other azimuths. The subjects of observation have been the Sun, Moon, planets and fundamental stars; also stars for which accurate places are required by Sir David Gill in connection with heliometer observations of major planets; and comparison stars for the opposition of *Eros* in 1900, from the list in the circulars of the *Eros* Committee of the Astrographic Conference.

One hundred and forty-five observations of stars both by reflexion and direct, and eighteen observations by reflexion only, have been made during the year.

Regular observations of flexure have been made throughout the year.

In October a re-determination of the division errors of the 45° divisions was made for the fixed circle, the microscopes of the movable circle being temporarily mounted on it as supplementary microscopes. It is intended to continue these observations so as to obtain the division errors of the circles by the process of subdivision of arcs of each circle separately for comparison with the results obtained by the symmetrical process previously used, in which both circles were observed simultaneously, and arcs of the fixed circle were compared with different arcs of the movable circle, on the other side of the axis. This will be taken in hand as soon as the observations of the *Eros* comparison stars come to an end for this season.

Equatorials.—Occultations of 17 stars and of *Saturn* by the Moon have been observed by one or more observers during the year. Observations of the partial eclipse of the Sun were made on May 28. These observations are given in *Monthly Notices*, vol. lxi. 4.

28-*inch Refractor.*—Measures of distance and position-angle have been made of 388 double stars, each star, when the components are under 1″·0 apart, having been observed on the average on $2\frac{1}{2}$ nights. Of the 388 stars 111 were under 0″·5 apart, 116 between 0″·5 and 1″·0, 87 between 1″·0 and 2″·0. Of the remaining 74 over 2″·0, a large part are third stars with close pairs, and others are difficult on account of the difference in magnitude. The following list gives a few of the more interesting stars measured during the year:—

	Mags.	Dist. ″		Mags.	Dist. ″
Capella	1 , 1	0·1	42 Comæ	5·5 , 5·9	0·3
κ Pegasi	3·9 , 5·0	0·1	β 883	7·0 , 7·0	0·3
β 1266	7·2 , 7·5	0·1	γ^2 Androm.	5·0 , 6·2	0·3
β 524	6·0 , 7·0	0·2	OΣ 269	6·5 , 7·0	0·3
β 525	7·0 , 7·0	0·2	β 552	6·9 , 10·2	0·4
68 Comæ	6·5 , 8·0	0·2	ζ Herculis	3·0 , 6·5	0·6
Σ 2367	7·0 , 7·5	0·2	OΣ 225	5·2 , 11·2	0·8
ε Hydræ AB.	3·5 , 6·0	0·2	Procyon	1 , 10	4·8
ζ Bootis	3·5 , 3·9	0·2	Aldebaran	1 , 14	31·4

Good sets of measures of 70 *Ophiuchi*, β 883, ζ *Herculis*, and κ *Pegasi* have been obtained, the last-named star, which is now at an interesting part of its orbit, having been observed on fourteen nights since last July.

The observations of greatest interest made during the year are those of *Capella* as a binary star. On April 4 it was found that there was a distinct elongation, and measures of position-angle were made and have been continued at every favourable opportunity through the year. The observations from April 4 to May 29 are given in *Monthly Notices*, vol. lx. No. 9, and the observations from July 10 to December 10 with a provisional orbit and a brief discussion in *Monthly Notices*, vol. lxi. No. 2. Since these were published observations have been obtained on six nights in December and January which are in satisfactory accordance with them. κ *Pegasi*, which is now quite as difficult an object as *Capella*, the distance of the components being less than 0″·1, has been observed recently on six of the nights on which *Capella* was observed.

Thompson Equatorial.—Work with this instrument has been almost entirely confined to the 26-inch refractor, with which 274 photographs have been taken during the year. Of these photographs 161 are of *Eros*, the planet being shown with measurable images on 122 of them, taken on fifty-two nights. The series was begun on July 18, and eighteen photographs were taken on sixteen nights between this date and September 25 for the position of the planet. Photographs were taken whenever possible from October 1 onwards in positions giving the largest available parallactic displacement on both sides of the meridian, and also on the meridian, and successful photographs were secured on thirty-six nights between October 1 and December 31. Similar observations were made with the Astrographic Equatorial, and photographs have been secured on forty-seven nights between October 1 and December 31.

A good series of photographs of Comet *b* 1900 was obtained, the comet being successfully photographed on eighteen nights.

Nineteen successful photographs of double stars and three of *Neptune* and his satellite were obtained, the occulting shutter being used, and 18 plates of *Polaris* and *Regulus* for parallax. Of the remaining photographs, 14 were of the *Pleiades* and *Præsepe* for examination of the distortion of the object-glass, 22 for adjustments of the object-glass on the equatorial, and 12 were taken to test plates in view of the eclipse of 1900 May 28.

With the reflector two photographs of the cluster M 37 *Aurigæ* (exp. 2^h and 1^h) and two of the *Pleiades* (2^h and $2\frac{1}{4}^h$) have been taken in the principal focus. Thirty-two photographs have been taken for the adjustment of the spectroscope, but the spectroscopic observations had to be discontinued owing to pressure of other work inconnection with the eclipse in May, and in the latter part of the year owing to the observations of *Eros*.

Astrographic Equatorial.—580 plates, with 1579 exposures, have been taken on 145 nights. Of these 101 have been rejected, viz. 10 because the exposure was interrupted by cloud, 16 because the plates did not come up to the standard in showing faint stars, 29 owing to bad guiding or wrong setting, 13 for photographic and 18 for miscellaneous defects.

Of the 494 successful plates, 153 were for *Eros*, now just past opposition, the planet being shown with measurable images on 153 of these, taken on 47 nights between October 1 and December 31. Of the others, 168 were for the Chart, 137 for the Catalogue, 12 for adjustments, 6 for typical areas, and 3 for the field round Comet *b* 1900.

The following table shows the progress of the photographic mapping of the heavens to the end of 1900:—

	Catalogue.	Chart.
Number of successful fields on 1899 December 31	1050	1062
" " " taken in 1900	137	168
Number previously passed, rejected in 1900	67	127
Number of successful fields, 1900 December 31	1120	1103
Number still required	29	46

Positives on glass of 120 chart plates were made during the year, which, with the 990 reported last year, make a total of 1110, of which 34 are duplicates.

During the year 1900 152 plates were measured in both direct and reversed positions of the plate by two measurers, who measured the 6^m and 3^m images respectively. The measurement of the Greenwich zones is completed from 64° to 74° N. Dec., with about half of the zone between 74° and 75°, making a total of 687 plates out of 1149, and covering about 1388 square degrees out of 2087. The total number of stars measured in this area is 105,000, while the number in the B.D. is 14,975. The average

number of stars measured per square degree is 75, which is almost exactly 7 times the number in the B.D.

The printing of the measures has been completed for zones 65°, 66°, and 67° during the year. Adding to these zone 64°, which was printed in 1899, the measures of 268 plates out of 1149 covering 586 square degrees out of 2087, or about one quarter of the whole, is now through the press. It may be of interest to notice that these measures are printed in 336 pages of the size adopted in the Greenwich volumes.

The counting of the stars on the chart plates which was begun last year has been continued, and Zones 65° and 66° are completed, and about one quarter of Zone +67°.

The following table gives the number of stars in the three zones obtained with exposures of 40^m, 6^m and 3^m, and 20^s, compared with the number given in the B.D. and the number of stars given in that work down to $9^m.0$. The first line for each zone gives the total number of stars shown, and the second line the number of stars which are shown twice, *i.e.* on each of the overlapping series of plates.

Zone.	No. of Sq. Degrees.	Number in B.D. $9^m.0$ and brighter.	Number in B.D. Total number.	Number shown on Photographs. Exposure 20^s.	Number shown on Photographs. Exposure 3^m and 6^m.	Number shown on Photographs. Exposure 40^m.
65°	149	762	2,005	2,476	9,245	47,080
				1,473	7,109	39,401
66°	144	611	1,744	2,157	9,503	45,333
				1,294	7,213	38,631
67°	43	193	494	494	2,67	15,335
($0^h.0^m-7^h.30^m$)				306	1,932	13,058
Totals	336	1,566	4,243	5,127	21,421	107,748
				3,073	16,254	91,090
Number per Square Degree		4·66	12·63	15·26	63·8	319·9
				9·15	48·4	271·1

The ratios of these numbers to the number of stars given in the B.D., *i.e.* to column 4 of the above table, are

Zone.	$9^m.0$ and brighter.	Total No. in B.D.	Exp. 20^s.	Exp. 3^m and 6^m.	Exp. 40^m
65°	·380	1	1·235	4·61	23·5
			0·735	3·55	19·7
66°	·350	1	1·237	5·45	26·0
			0·742	4·14	22·1
67°	·391	1	1·000	5·41	31·0
($0^h\ 0^m-7^h\ 30^m$)			0·620	3·91	26·4
Means	0·374	1	1·157	5·16	26·8
			0·699	3·87	22·7

Photoheliograph.—Photographs of the Sun have been obtained on 162 days; those on 121 days were taken with the Thompson photoheliograph of 9 inches aperture, and those on the remaining 41 days—viz. between March 10 and June 17, whilst the Thompson instrument was dismounted for use in the eclipse expedition of 1900 May 28—with the Dallmeyer photoheliograph of 4 inches aperture. Of the photographs taken 350 have been selected for preservation, including 17 with a double image of the Sun, taken to determine the position of the wires with reference to the parallel of declination, and six photographs of the partial eclipse of May 28. Photographs have also been received from India up to 1900 July 4, and from Mauritius up to 1900 April 10, the year ending on the latter date being represented on 362 days out of the 365 by a photograph from one or other of the three observatories.

The measures and reductions for 1899 have been completed and the results wholly passed for press. No great progress has been made with the measures and their reduction for 1900; the work having been partly laid aside in order to proceed with the new catalogue of the library. The Greenwich photographs have been measured in duplicate up to the end of 1900 March, the Indian up to the end of 1900 May, and the Mauritius photographs as far as received. The reductions for the Greenwich photographs are complete up to 1900 March 9, for the Indian to 1900 May 1, and for those from Mauritius as far as received.

The solar activity as shown in the numbers and areas of sunspots has been very small during the past year 1900. The mean daily spotted area of the Sun for 1899, expressed as usual in millionths of the visible hemisphere, was 111, as compared with 1464 for the year of maximum, 1893, and a rough estimate for 1900 would place the corresponding area as under 80. The actual minimum must therefore be close at hand, and may be expected in the course of the present year. The area for 1889, the year of minimum in the preceding cycle, was 78.

The publication of the various longitude determinations made in the years 1888–1898 has been taken in hand. The determination Greenwich-Paris made in 1888 is printed with the exception of a few pages. The determination of the same arc made in 1892 has been re-examined, and copy for press prepared. Copy for press of the longitude determinations Greenwich-Waterville-Canso-Montreal is proceeding. As stated in the last report, arrangements have been made for a re-determination of the Paris longitude in conjunction with observers from the Paris Observatory. It is proposed to undertake this determination in 1901 October and in the spring of 1902.

An expedition to observe the solar eclipse of May 28 having been sanctioned by the Admiralty, the Astronomer Royal, Mr. Dyson, and Mr. Davidson went to Ovar in Portugal for this purpose, leaving Greenwich on May 11, and returning to Greenwich again on June 5. A preliminary account of the observations

presented at a joint meeting of the Royal and Royal Astronomical Societies is given in an appendix to *Monthly Notices*, vol. lx. It is hoped to send two observers to make observations of the forthcoming eclipse on May 18—Mr. Dyson to Sumatra, and Mr. Maunder to Mauritius.

The printing of the annual volume of *Greenwich Observations* for 1898 and of the *Second Ten-year Catalogue* is completed, and these volumes will be distributed shortly. The volume for 1899 to the end of the *Annual Star Catalogue*, and the heliographic results, are printed. As stated previously, the measures of the astrographic plates are printed as far as Dec. 67°, which is approximately one-quarter of the whole.

Good progress has been made with the re-arrangement and new card catalogue of the library. The astronomical books and periodicals and about one-quarter of the pamphlets have been arranged, and a card catalogue of them has been made. A duplicate catalogue, to be arranged alphabetically under authors' names, is being made, the original, arranged in the order of the books on the shelves, serving as a subject catalogue.

Royal Observatory, Cape of Good Hope.

The material for the steel observatory of the new Transit Circle reached the Cape in April, and its erection was completed in December. The new transit circle itself has not yet reached the Cape. It was ready for preparatory inspection in May, and Mr. Simms took the utmost care to carry out suggested alterations made from time to time by H.M. Astronomer when he was in England. The instrument was finally passed in October by H.M. Astronomer as ready to be dismounted and packed for shipment; it is now probably on its way to the Cape.

The 24-inch photographic object-glass of the McClean equatorial was returned to Sir Howard Grubb for correction on the 31st October 1899, but it has not yet been returned by him.*

Vol. v. of the Cape *Annals*, being the third and last part of the *Cape Photographic Durchmusterung*, has been distributed.

Vol. viii. part 2 of the *Annals*, being "Heliometer Investigations on the Parallaxes of the Principal Fixed Stars of the Southern Hemisphere," has been passed through the press.

The Cape General Catalogue of 1905 stars for 1865, based on the meridian observations made under the direction of Sir Thomas Maclear, 1860 to 1870, has been distributed.

The *Annual Results of Meridian Observations*, 1866–70, have been printed and issued.

The *Annual Results of Meridian Observations*, made under

* A telegram has since been received from Sir David Gill saying that the glass has arrived safely at the Cape.

the direction of Mr. Stone, 1877, have been printed and issued; the printing of those for 1878–79 is well advanced.

The *Annual Results*, 1896 and 1897, containing the separate meridian observations of the Astrographic Catalogue-Plate standard stars for the zone decl. $-40°\ 0'$ to $-44°\ 0'$, reduced to the equinox 1900, have been passed through the press. Similar results for 1898 for the zone decl. $-44°\ 0'$ to $-48°\ 0'$ are printed as far as R.A. $19^h\ 46^m$. The copy for press of the results for 1899, zone $-48°\ 0'$ to $-52°\ 0'$, is in the hands of the printer.

Considerable advance has been made in the preparation of a general catalogue of the standard stars for plates of the Cape astrographic zone.

The day-numbers for the year 1902 have been distributed. Those for 1903 have been printed, and will be distributed with the annual report for 1900.

The work of the transit circle has been largely devoted to very elaborate determination of the personal equation in Right Ascension as affected by the stars' magnitude. Transits were observed over the first half of the wires "without screen," and over the second half "with screen," or *vice versâ*. The whole of the results have been discussed. The following instructive table gives some of them :—

Corrections depending on Magnitude to be applied to the Clock Times of Transits by the different Cape Meridian Observers.

Star's decl. 0° to ± 10°.

Magnitude.	Pett.	Cox.	Power.	Pead.	Woodgate.	Cochrane.
	s	s	s	s	s	s
0	0·000	0·000	0·000	+0·058	+0·019	+0·032
1	·000	·000	·000	+ ·042	+ ·015	+ ·025
2	·000	·000	·000	+ ·026	+ ·011	+ ·017
3	·000	·000	·000	+ ·013	+ ·006	+ ·009
4	·000	·000	·000	·000	·000	·000
5	− ·009	− ·003	− ·004	− ·011	− ·006	− ·010
6	− ·026	− ·009	− ·012	− ·022	− ·013	− ·021
7	− ·051	− ·017	− ·025	− ·031	− ·021	− ·032
8	− ·085	− ·027	− ·041	− ·038	− ·029	− ·044
9	− ·127	− ·039	− ·062	− ·045	− ·038	− ·058
10	− ·176	− ·053	− ·087	− ·050	− ·047	− ·071

These corrections were obtained by independent discussions of observations in which the absorption of light by the screen corresponded to 1·8 and 3·6 magnitudes. The results given independently by both screens agreed satisfactorily. They show that whilst there is considerable range in magnitude personality for different observers, yet *every* one of the observers records the time of transit of faint stars later than that of bright stars, and

that, as a rule, this personality is greater for a given difference of magnitude in the case of faint stars than in that of the brighter stars.

A curious fact is that the difference of personality remains nearly the same for stars of very different declination. Thus, for the mean of six observers we have :—

	From Recent Results.		
Star's Magnitude.	Decl. 0° to ±10°.	Decl. −40° to −52°.	Originally given for the 1890 Catalogue, p. xliv.
	s	s	s
1	+0·014	+0·023	+0·042
2	+ ·009	+ ·014	+ ·028
3	+ ·005	+ ·006	+ ·014
4	·000	·000	·000
5	− ·007	− ·008	− ·014
6	− ·017	− ·018	− ·028
7	− ·030	− ·029	− ·042
8	− ·044	− ·042	− ·056
9	− ·061	− ·056	− ·070
10	− ·080	− ·072	—

The latest results should be adopted for the 1890 catalogue, instead of those given at p. xliv. of the work in question. It will be observed that the difference is mainly in corrections to the brighter stars, which were, in fact, not strongly determined in the previous operations.

The results of these investigations are being employed in the formation of the General Catalogue of 8556 standard stars of the astrographic plates.

The general work of the transit circle has been confined to observations of the stars of the new working list which is described in the last report. The observations made with the transit circle during the year have been :—

Transits for personality depending on magnitude ...	4204
Observations for R.A....	3465
Determinations of Z.D.	2824
" " Collimation	78
" " Level	177
" " Azimuth	202
" " Run	147
" " Nadir	148
" " Flexure	19

The reductions of the meridian observations to apparent R.A. and declination are complete to December 31, but in consequence

of the absence of two computers at the front, the star reductions to mean place are only partly computed and are not yet applied.

Observations of 78 separate phenomena of occultations of stars by the Moon were obtained as follows :—

	DB.	DD.	RB.	RD.	Total.
Predicted by the N. A. Office	0	17	0	17	34
Other occultations	0	40	0	4	44
Total number of separate phenomena					78

Of these 20 were observed by two observers,
5 „ „ three „
and 1 „ „ four „

Giacobini's comet was observed on four nights with the McClean telescope. Comets Brorsen and Finlay were searched for on three and four nights respectively, but were not seen.

In searching for Brorsen's Comet Mr. Lunt noted five previously unrecorded nebulæ on the region covered by the astrographic plate (−47°, $22^h\ 5^m$), but they are not shown on any photographic plate yet taken.

As the 24-inch photographic object-glass of the McClean telescope has been with Sir Howard Grubb in Dublin during the whole year, the 18-inch visual telescope has been employed in the measurement of double stars. Without making the discovery of double stars a matter of special research Mr. Innes has detected 31 previously unrecorded pairs, of which the following are naked-eye stars :—

	Mag.	Mag. of Comes.	Distance. "		Mag.	Mag. of Comes.	Distance. "
β Crucis	1·7	11·5	44	Lac 8625	5·9	...	0·3
Lac 9112	5·4	14·5	41	P. V. 122	5·9	12·0	20·0
Lac 3811	5·4	12·0	18·2	θ Pictoris	6·3	...	0·43
Lac 6277	5·4	13·0	5·5	Lac 5589	6·5	...	0·3
π_2 Gruis	5·8	12·5	4·7				

Fourteen of the remainder are under 5″ distance and the others are distant *comites* to stars between 6·5 and 8·0 mag. Mr. Innes has also detected thirteen unrecorded double stars with the 7-inch equatorial, of which 8 are under 2″ in distance. Six unrecorded double stars have been found by Messrs. Cox and Pead with the transit circle and two on the astrographic plates.

With the Repsold micrometer attached to the 18-inch visual telescope of the McClean equatorial, 816 measures of distance, and 860 measures of position angle of 430 different double stars have been made. Each measure is the mean of at least four pointings. Of these measures 228 have been made by Mr. Lunt and 588 by Mr. Innes. The stars selected for measurement have

been, as a rule, pairs which were never measured before, or which have not been observed since Herschel's expedition to the Cape. Of these, 70 pairs are under 1″ distance and 56 between 1″ and 2″. A considerable amount of attention has been devoted to observations of *α Centauri* as a double star.

Regular observations of all oppositions of major planets with the heliometer have been continued; the following were secured in 1900:—

	No. of Observations.
Opposition of *Jupiter*	53
„ *Saturn*	40
„ *Uranus*	44
„ *Neptune*	66

The triangulation of the *Jupiter* comparison stars for 1898 has been completed; the work involved observations of 86 distances in the triangulation and 26 standards in 1900, in addition to 36 distances and 17 standards measured in 1899. The triangulation of the comparison stars for *Uranus* 1897–1900 and *Saturn* 1898 is nearly completed; 106 distances and 36 standards in this triangulation having been observed in 1900. The triangulation of the comparison stars for *Neptune* 1897–1900 is also nearly completed; 27 distances and 11 standards in this triangulation were observed in 1900.

Three sets of heliometer observations of the conjunction of *Jupiter* and *β Scorpii* were made. The triangulation of the circumpolar area has been completed by the observation of 83 distances and 26 standards during 1900, in addition to 513 distances and 168 standards observed in former years.

The partial eclipse of the Sun on November 22 (civil time) was observed with the heliometer, 88 pointings were made of the distances of the cusps. Twenty-six photographs of the eclipse were made with the photo-heliograph.

During the year the reduction of the heliometer observations has been confined to the distances measured in the polar triangulation; the reduction of the instrumental distances is complete; the computations of the corresponding tabular distances from the meridian observations and the formation of the equations of condition for the discussion of the results are also finished, but the normal equations have not yet been formed.

H.M. Astronomer has gratefully to acknowledge very valuable series of observations of comparison stars from the principal meridian observatories.

The long computations connected with the discussion of the heliometer observations of *Jupiter's* satellites are nearly completed.

With the Astrographic Telescope the following work has been accomplished: —

	No. of Plates.	No. of Exposures.	Duration of each Exposure.
Triple image Chart plates, passed * ...	103	309	30^m
" " rejected ...	44	132	30^m
Revision Catalogue plates	172	516	$6^m, 3^m, 20^s$
Iris plates †	7	42	3^m to 1^m
Galactic comparison plates	6	12	10^m
Various (focal adjustments, &c.) ...	14	...	...
	346	1011	

With reference to the revision Catalogue plates, it is intended, as mentioned in the last report, to repeat the whole series in order to bring the epoch at which the plates are taken more nearly to that at which the standard stars were observed on the meridian. The question is now under consideration whether the standard stars, at least, should not be measured on both sets of plates. The new measuring machine, devised by H.M. Astronomer and constructed by Messrs. Repsold, has continued to give the greatest satisfaction. A second machine of the same type was brought into use early in 1900, but the training of additional observers and the loss of two trained observers has limited the expected output of work. During the year, 124 catalogue plates of the Cape zone, containing 71,655 stars, have been measured in both coordinates, in each of the two reversed positions of the plate; all the standard stars on each plate have been measured by both observers. When either coordinate of any star, as measured in one position of the plate, differs by $0''\cdot6$ from the corresponding coordinate resulting from the measure in the reversed position of the plate, the observations in both positions are repeated. The measures of 248 plates, besides two plates rejected after measurement, have now been converted into rectangular coordinates in arc, and the results for 163 plates have been examined and prepared for press.

This enumeration includes the measurement of nine circumpolar plates containing 2095 stars. The Cape has taken over from Melbourne the observation and measurement of the circumpolar zone to 2° S.P.D., because the data for this work will be greatly strengthened by the results of the heliometer triangulation of the circumpolar area. An independent determination of the stars of this area has been undertaken by Professor Jacoby from an earlier series of plates.

The revision of Kapteyn's C.P.D. lists mentioned in previous reports has now been practically completed by Mr. Innes, and the results are ready for press. The following new variable stars have been detected in the course of this year's work :—

* The total number of triple image Chart plates now taken and passed is 362.

† Completion of series taken July to December, 1899. See last report.

		1875. h m ° ′	Range.	Period. d
C.Z. VII.	2258	7 31·9 − 73 7	9·1 to inv.	400 ±
„ IX.	3759	9 48·6 − 53 36	9·3 to inv.	360 ±
Gilliss P.Z.	9192	13 9·5 − 83 34	7·7 to inv.	273 ±
„ „	9628	13 43·7 − 77 11	8·6 to inv.	...

Besides these, several other suspected and known variable stars are under observation.

A list of all stars in the C.P.D. marked ? or X has been prepared, and considerable progress has been made in examining the objects of this list. Stars marked ? by Kapteyn are those of which he considered the existence as not satisfactorily proved; so far as the revision goes, about three-fourths of them are found actually to exist. The stars marked X (image of star somewhat nebulous) are generally found to be very minute double stars, in no case showing any decided nebulosity.

The weather on November 14, 15, 16, and 17 was persistently cloudy; no observations of *Leonid* meteors could be made.

In the Physical Laboratory Mr. Lunt has been occupied with investigations on the spectra of Oxygen, Silicon, Aluminium, Boron, and Sulphur.

The records of the seismograph have been forwarded monthly to Professor Milne during the year.

The Geodetic Survey of Rhodesia has been pushed forward as steadily as circumstances would permit. Mr. A. Simms with his assistants, Messrs. Heatlie and Antrobus, reached Beira on March 31, after having spent three months at the Cape during the season when the rains rendered transport near the Zambesi impossible. A base line near Salisbury has been measured with the Jäderin apparatus and the points selected and beaconed for its connection with the chain and many stations were occupied for observations of angles. To complete the whole work to the Zambesi there remain the measurement of the angles at eleven points already beaconed, the selection of six to eight additional stations, and the measurement of angles at these new stations. This work will probably be completed in July. Mr. Antrobus is now on his way to the Cape bringing for comparison the Jäderin wires used in measuring the Salisbury base.

The operations of the Anglo-German Boundary Survey are in steady progress, but have been delayed by the exceptional difficulties of the country, want of water, &c. A base has been measured with Jäderin wires near the northern point of the arc (lat. 22° S.), and Major Laffan and Lieutenant Wettstein expect to return to the Cape about August 1 next, in order to obtain the data from their observations for beaconing the actual boundary.

The printing of the re-reduction of Bailey's Survey mentioned in last report is still incomplete, owing to delays on the part of the Cape printers. The work will now soon be ready for distribution.

The meteorological observations made during 1900 have been communicated to the Cape Meteorological Commission.

Two computers, also the optical fitter and the carpenter, were called out as members of the Cape Volunteer Artillery for active service at the seat of war in October 1899, and have been absent from the Observatory during the whole of the year 1900. Mr. C. Ray Woods and Mr. S. Goodman retired from the Observatory service on November 30 and September 30 respectively; their places are not yet filled, and the work of the Observatory has necessarily suffered by the absence of so large a part of its staff.

H.M. Astronomer was absent on leave from April 8 until November 20, Mr. S. S. Hough remaining in charge. During his visit to Europe H.M. Astronomer attended the meetings of the Permanent Committee of the Astrographic Congress and of the International Geodetic Association, which were held at Paris in July and September respectively; he was also present, as a delegate of the Cape Colony, at the meetings held at Burlington House for organisation of the International Catalogue of Scientific Literature. He was also much occupied in England in connection with the great African Geodetic Arc, the inspection of the new transit circle, and the details of plans and experiments in connection with the construction of a sidereal clock of entirely new design which is under construction by the Cambridge Scientific Instrument Company for use with the new transit circle.

Royal Observatory, Edinburgh.

The grounds and Observatory buildings have been maintained in good order by H.M. Office of Works, Edinburgh. The painting of the interior of the buildings, which was postponed after their erection, to allow the plaster work to become perfectly dry, was commenced in the end of October, and was approaching completion at the end of the year. With the exception of the injury to the east dome, referred to below, very little damage, either to the residences or the Observatory, resulted from the great storm of December 20–21. The plantations of young trees also fortunately suffered little, considering the violence of the gale.

It is with much regret the decease is here recorded of the late Dr. Charles Piazzi-Smyth, ex-Astronomer-Royal for Scotland and Emeritus Professor of Practical Astronomy in the University of Edinburgh. He died on February 21 at Clova, Ripon, Yorkshire, in the 81st year of his age. Amongst the obituary notices in the present number of this publication will be found an account of his life and astronomical work.

The time services for the cities of Edinburgh and Dundee have been carried on as in former years, the signals by time-ball and gun-fire in Edinburgh and by gun-fire in Dundee being

controlled by the Molyneux mean-time clock of this Observatory. The ball was not raised on 1900 January 26 on account of the severity of the gale. There was no gun-fire at Edinburgh on May 11 owing to a derangement of the magnets of the controlled clock at the Castle, and again on June 12, the electric contacts having been injured during a thunderstorm. From December 21 to 25 the city time service was completely cut out of connection with the Observatory, the wires having been broken down by a tree falling across them during the violent gale of the night of December 20. Only one incorrect signal was given during the year, the Edinburgh gun being fired two seconds slow on December 17, owing to a displacement of the seconds hand of the Castle controlled clock. With these exceptions the time service has worked satisfactorily.

The observations with the Troughton & Simms Meridian Circle were made throughout the year by Dr. Halm and Mr. Clark. The measurements of Sir David Gill's 2798 zodiacal stars were continued, on all favourable occasions, according to the programme adopted in the previous year. The errors of the instrument were controlled at short intervals by means of the collimators and observations of *a Ursæ Minoris* in both culminations, and every opportunity was taken for determining corrections to the standard clock used for the time service of the Observatory and city. In the summer of this year the Observatory received, through the kindness of Lord McLaren, the loan of his 4-inch heliometer for the purpose of measuring the planet *Eros* at the time of its opposition. Dr. Halm, assisted by the Observatory engineer, Mr. McPherson, mounted and adjusted the instrument in the hut previously occupied by the 12-inch Browning reflector. Throughout the autumn all the clear nights available were taken advantage of by Dr. Halm to redetermine the angular value of the scale divisions by observations of the *Perseus* zone and three stars in the *Pleiades*. The faintness of the planet during this appearance, however, did not allow of more than two measurements with this instrument being obtained—viz. on December 26 and December 29. On the other hand 51 observations of the planet at considerable hour-angles were secured with the 15-inch refractor by Dr. Halm, during the time from October 21 to December 12, while Mr. Heath measured the planet with the same instrument near the meridian seven times, and made a number of measures of a few other minor planets during the course of the year. Unfortunately the accident to the dome, referred to, on the night of December 20 put a sudden end to these observations just at the time of the closest proximity of *Eros* to the Earth. Four measures of the position of Comet 1900 *b* were also made by Mr. Heath and Mr. Clark with the 15-inch refractor.

Some observations of *Eros* were also made with the Meridian Circle, nine by Mr. Clark and four by Dr. Halm. In spite of the large aperture of the instrument—8 inches—only one

of these observations could be made with the bright field illumination.

The reduction of the Edinburgh meridian observations made between 1834 and 1845 has been continued by Dr. Halm and Mr. Clark, who received valuable assistance in this work from Mr. Neustadt, the temporary computer. The work is now in process of arrangement for the press.

At the invitation of the Joint Eclipse Committee of the Royal Society and Royal Astronomical Society, Professor Copeland undertook to organise an expedition to Spain to observe the total eclipse of the Sun of May 28. A preliminary report on this expedition will be found at p. [49] of the Appendix to vol. lx. of the *Monthly Notices*.

The meteorological observations have been made by the staff of the Observatory on the same lines as in former years. The bi-daily readings of the barometer, wet and dry bulb thermometers, estimates of wind and cloud, and daily readings of the shaded and exposed maximum and minimum thermometers, have been continuous throughout the year. A monthly copy of these observations has, as usual, been supplied to the Secretary of the Scottish Meteorological Society for the use of the Registrar-General for Scotland, and the monthly means have been published in the Registrar's returns. The Robinson Anemometer and King's Barograph have also been in operation without interruption, and the weekly readings of the Rock thermometers at Calton Hill have been continued. A Campbell-Stokes sunshine recorder was mounted in December, and arrangements made for commencing observation of this important meteorological element on 1901 January 1.

The two bifilar pendulums and their photographic-recording apparatus have been in operation throughout the year. A few slight tremors have been recorded, but they are not of an interesting character. At the request of the Seismological Committee of the British Association, a Milne Seismograph was erected in the beginning of December, and was put into operation on the 5th of that month. The instrument, which is of the horizontal boom type, is placed in the basement of the Observatory buildings, the pier on which the pillar stands being built of granite blocks bedded in cement on the porphyritic rock of which Blackford Hill is composed. The first record of an earthquake with this instrument was found on the photographic paper for the morning of December 25, in agreement with similar records obtained at Shide, Kew, and San Fernando. The disturbance began at $5^h\ 16^m$ a.m. and ended at $6^h\ 28^m$ a.m.; the maximum was at $5^h\ 56^m$, and had an amplitude on the photographic paper of about 4 mm.

The violent gale which passed over Scotland on the night of December 20–21 was unfortunately the cause of great damage to the east dome. It was found that by the fracture of three of the brackets holding the lateral guiding wheels the dome was

forced horizontally off the wheels of the live ring. The accident was at once notified to the Surveyor of H.M. Office of Works, Edinburgh, by whom immediate steps were taken to have the repairs executed by the maker of the dome, Sir Howard Grubb. On December 31 it was successfully replaced on the live ring under the superintendence of Mr. Rudolf Grubb. At the date of this report the repairs have not been completed, but all necessary precautions have been taken to prevent further damage. This storm was of altogether exceptional violence, and an exceedingly interesting record of it has been secured on the Robinson anemograph. For several days preceding the 20th the weather had been of a stormy character, high winds prevailing. The storm appears to have culminated about midnight of the 20th, the velocity for the hour 11 p.m. to midnight having been not less than 93 miles.

The *Leonid* meteors were expected on the nights of November 14, 15, and 16, and arrangements were made for observing them on each of these nights. The last two nights were hopelessly cloudy, but the 14th was fairly clear till the early morning. Nine meteors were seen having all the characteristics of *Leonids*, with this exception, that they did not radiate exactly from the predicted point. Their apparent paths were carefully plotted by Mr. Clark on a specially prepared map, and it was found that four of the trails radiated from the same point—viz. R.A. $9^h\ 49^m$; decl. $+29^{\circ}\cdot2$. The other five trails radiated from a very small area whose centre was situated at R.A. $10^h\ 3^m$; decl. $+32^{\circ}\cdot2$. These meteors may perhaps be considered as belonging to the *Clino-Leonids.*

Some trial photographs with the Grubb 24-inch reflector were made in the end of the year by Mr. Heath, to test the regularity of the driving clock and the adjustments of the instrument. For this purpose the flat had to be resilvered. The clock was found to work admirably, and the careful adjustment of the instrument was taken in hand.

A summer course and a winter course of lectures in astronomy were delivered by Professor Copeland to the astronomy class in the University of Edinburgh.

Armagh Observatory.

The photographic micrometer referred to in last year's report has been employed in measuring some plates of the *Pleiades* and a plate of the spiral nebula M 33, kindly lent by Dr. Roberts. A second plate of the latter object has recently been received. The errors of the micrometer screw have been fully investigated. After many experiments it was found necessary, for the purpose of determining the division errors of the glass scale, to cut the plate in two lengthways, so that the divisions would be on the edge of the glass, along which an auxiliary scale could be made

to slide. The scale and its stage were therefore sent to Messrs. Troughton and Simms early in November for alteration.

Towards the end of the year a great deal of time was spent on the examination of the reductions of about 160 stars of the Armagh Catalogue in order to clear up errors pointed out by Dr. Ristenpart. The results of this work will shortly be communicated to the Society.

The meteorological work, which includes tabulation of the records of the anemograph and self-recording rain-gauge, has been continued on the same lines as since 1884.

Cambridge Observatory.

Meridian Circle.—In consequence of the unfavourable weather, observations were made with this instrument on 91 nights only during the year. Frequent observations of standard stars, especially *Polaris*, were taken by day, for time and instrumental correction.

All the faint stars in the Cambridge portion of the catalogue of the *Astronomische Gesellschaft*, of which the places there given depend on a single observation, have been re-observed several times, the reductions completed, the places reduced to Epoch 1875·0, and the results arranged in order of right ascension.

The work of observing Sir David Gill's list of Heliometer Comparison Stars, begun in 1899 March, was completed during the early part of the year. To this end 459 observations were taken. These are all reduced to mean equinox at the beginning of the year, and the results tabulated.

The list of Harrow Occultation Stars, furnished by Colonel Tupman, with the exception of a very few difficult faint ones, has been observed; the resulting apparent places are all reduced to mean equinox at the beginning of the year, and the mean places tabulated.

At present the instrument is chiefly used for the observation of stars comprised in Sir David Gill's catalogue of 2798 zodiacal stars for the Epoch 1900. Of these, 1127 observations have been taken during the latter part of the year, and, besides these, 157 observations of zodiacal stars from other catalogues. These are all reduced to apparent right ascension and apparent declination. The work of reducing them to mean equinox at the beginning of the year has been begun.

As an essential part of the work, there have also been made 612 observations of standard stars—chiefly *Nautical Almanac*—for clock error; and for instrumental deviation 67 observations of *Polaris* at the upper transit and 79 at the lower, and 62 observations of other close circumpolar stars. The observations of *Polaris* have also been utilised in making a fresh determination of the intervals of the wires.

The nadir point, level, and line of collimation have been regularly observed, and the constants for instrumental correction have been obtained from 137 equations.

After each observation for level and line of collimation, the transit wires have been always adjusted so as to leave the observations practically free from error of collimation and from the effect of diurnal aberration.

Toward the close of the year a request came from Dr. Auwers that all the Cambridge transit observations made during the years 1846–1869 should be reduced to Epoch 1855·0, and formed into a catalogue. He also requested that a preliminary list of the stars that had been observed should be sent to him as soon as possible. This preliminary list is in course of preparation, and stars observed during these years of R.A. $0^h - 10^h$ are now arranged in order of right ascension.

Sheepshanks Photographic Equatorial.—At the date of the last report considerable alterations in and additions to the instrument had just been completed. They were designed to close in the elbow-joint and prevent the free access of air to the tube and mirror. Definition has been considerably improved by the alterations.

In March the new guiding apparatus and plate-carriers were delivered. Their design is based upon Dr. Common's form of apparatus, with some elaboration of detail. The screws which move the plate-holder along rectangular slides have divided heads; the guiding eyepiece has motion in two coordinates with divided scales; the eyepiece is a low-power compound microscope, so that the eye is at a convenient distance—about four inches—behind the plane of the plate, and the observer's face is not pressed flat against the slides, as it would be if a common eyepiece of half-inch focal length were used. A large finding eyepiece has been made to fit on in place of the plate-carrier. It has a power of about 25, and a field of view rather more than a degree in diameter. The eyepiece contains a network of silver wires, which can be illuminated at pleasure, and by means of which the field to be photographed is properly centred, and a finding star selected and brought into the finding eyepiece.

On 1900 May 28 sixteen plates were obtained of the partial Solar Eclipse, with two exposures upon each. They have not yet been measured.

It had been recognised for some time that the figure of the plane mirror was not quite perfect, and, in May, Dr. Common very kindly undertook to refigure it. The mirror was dismounted and returned to Ealing on May 31, and on July 9 another mirror of the same size was received from Dr. Common in place of the old one, which proved to be slightly convex. During August and September the adjustments of the instrument were completely revised.

A first photograph of *Eros* was obtained on September 29; and since then the instrument has been devoted entirely to the

observation of the planet. A few days' work showed that in most respects the new guiding apparatus and accessories were completely successful, and the work has proceeded with but few instrumental troubles up to the present time. But the weather has been extremely unfavourable for diurnal parallax work.

Summary of Weather at Cambridge, 1900 *October to December.*

	Oct.	Nov.	Dec.
Clear all night...	2	1	1
Clear most of the night	6	2	2
Clear for an hour or two	14	8	12
Completely cloudy	9	19	16

In spite of the greatest endeavours to take advantage of every hour of clear sky, there were only seven nights between October 1 and December 31 on which it was possible to obtain a parallactic displacement of *Eros* greater than 25″. The greater part of the observations form incomplete series, useless for the diurnal method, but available for comparison with simultaneous observations at a distant station.

The whole of the exposures obtained up to December 31 have been carefully examined in the measuring machine, and classified according to the character of the image of the planet. The examination gave—

	Oct.	Nov.	Dec.
Measurable Images.			
Good	3	60	46
Fair	26	52	41
Faint	57	35	28
Very faint	37	18	12
Images Rejected.			
Too faint	55	12	13
Defective	30	24	19
Totals	208	201	159

Grand total, 568.

Of the images rejected as defective, the greater number showed no visible defect; but the observer noted that the exposures were perhaps interrupted by cloud. It has been judged best to reject without exception all images liable to suspicion on this account.

The full observing programme was to obtain four images of the planet per hour between the hour angles 6^h E. and W. The construction of the instrument prevents observation in greater hour angles. During two exposures of each series the planet was followed; during the other two the stars. The corrections to the driving required to follow the planet in R.A.

were obtained by altering the weights upon the dish of the pendulum. The motion in declination was obtained by turning slowly and continuously the divided head of the screw which moves the plate-holder in declination, completing a turn through one division in a calculated number of seconds. This method worked very satisfactorily.

The measuring machine, which has been made by the Cambridge Scientific Instrument Company, was completed at the end of November. A preliminary examination shows that the errors of screws and scales are extremely small, and that the settings are of a high order of accuracy. A description of the machine will shortly be communicated to the Society.

The Newall Telescope, Cambridge Observatory.

The Newall Telescope was used for observations on eighty-eight nights in the course of the year 1900.

During the greater part of the year the instrument was used in connection with the large four-prism spectrograph referred to in last year's report. The scale of the spectra obtained is approximately six tenth-metres per millimetre, and hence only the brighter stars can be examined with the instrument. Ninety-seven photographs of stellar spectra, nearly all involving long exposures, were obtained; many others have been rejected on account of insufficient exposure. Sixty-one photographs have been measured for determination of velocity in the line of sight and for other investigations not yet completed.

Some preliminary results for the case of α *Aurigæ* were communicated to the Society in March (*Monthly Notices*, lx. p. 418). Variable velocity has been detected in α *Persei*, and some of the results of the measurements were communicated to the Society in November (*Monthly Notices*, lxi. p. 12).

The four-prism spectrograph was dismounted at the end of April and sent to Algiers for use during the eclipse of the Sun on May 28: it was not received back again until the end of July. During this interval a camera was mounted on the eye-end of the equatorial in order that certain double stars might be photographed with enlarged images. But as there were only eleven nights in May, June, and July on which observations could be made, but little progress was made with this work.

The new micrometer for measuring spectrum photographs—Zeiss's Comparator—has been in use during a great part of the year. The silver scale is 100 mm. long, and this interval is divided into 500 parts. The errors of the division marks and of the micrometer screws were carefully investigated in July and August, and the corrections to be applied for each of the 500 marks were determined. This investigation of the scale was laborious, involving more than 6000 settings of the micrometer. The results are eminently satisfactory.

Dunsink Observatory.

Observation of the stars included in Sir David Gill's list of 2798 zodiacal stars has been continued by Mr. Martin throughout the year. The total number of meridian circle observations is 4915. These consist of 2036 in R.A. of the zodiacal stars, 287 for determining the error of the Dent sidereal clock, 65 for collimation, 72 for level, 61 for azimuth, 2036 observations of declination of the zodiacal stars, 270 for the equator point of the circle, and 65 for the nadir point. The error of runs of the microscopes was determined 23 times. The observations have been reduced to apparent place up to December 13.

The Ninth Part of the *Astronomical Observations and Researches made at Dunsink* was distributed in October. It contains the results of meridian circle observations of 321 stars—stars of reference for clusters and heliometer comparison stars observed at Sir David Gill's request. The average number of complete observations for each star is about four.

As far as the unfavourable weather allowed, work has been continued with the Roberts' photographic reflector in photographing star clusters, and, since September 24, in taking *Eros* plates. The season here was the worst for many years. During four months in summer only seven nights were fit even for meridian circle observations.

During the eclipse, on May 28, Mr. Martin observed the times of contact with the South equatorial and the march of temperature of two radiation thermometers. His results were communicated to the Royal Dublin Society, and were published in the *Proceedings* of that body. The director accompanied the eclipse expedition, fitted out by the Royal Irish Academy and the Royal Dublin Society, to Plasencia, in Spain, and obtained photographs of the corona with a 4-inch lens of 20-foot focus. The preliminary results of the expedition will shortly be communicated to the two Societies.

A large number of visitors throughout the year utilised the opportunity of observing with the South equatorial on the open nights—the first Saturday in every month.

The time service to Dublin has been continued as usual.

Durham Observatory.

The Almucantar, of which a description was published in the *Monthly Notices* of June last, has been in use by Professor Sampson and Mr. F. C. H. Carpenter on most favourable nights between July and November. An amount of useful experience has been gained, and the results are generally satisfactory; but the failure to obtain a chronograph, now long overdue from a firm of instrument makers, has given them a provisional character, and has prevented any conclusive work from being done.

The discussion of the Harvard eclipses of *Jupiter's* satellites has proceeded satisfactorily. One hundred and nineteen eclipses of III have been reduced, charted, and measured, and provisional values of the corrections to Damoiseau's elements have been deduced from them. An entirely independent discussion of the ordinary observations of III, extending over sixty years, has also been made, and the corrections thence deduced show a most satisfactory agreement with those found from the Harvard eclipses as far as the equations of conjunction are concerned. Meteorological observations have been carried out as heretofore.

Glasgow Observatory.

The transit circle was used during the year for the observations of the star *B.D.* 89° 37′ and of α and λ *Ursæ Minoris*, in continuation of the work which was begun four years ago. There were only 39 nights during the year on which faint objects, in the vicinity of the pole, could be observed for several hours, and these nights were, with the exception of three, devoted to these measurements. The reductions are up to date.

In the last three months a fresh attempt was made to photograph the spectrum of the *Andromeda* nebula by means of the slit spectroscope of the Breadalbane reflector. Although every possible opportunity was seized, only 33 hours of exposure could be secured till the end of the year, and the plate will probably again be lost. Long exposures were also given to the spectrum of the *Orion* nebula during the earlier part of the year.

The director, aided by three computers, has devoted a great deal of his time to the working up of the meteorological records which have accumulated during 33 years. The daily and yearly temperature curves and sunshine curves were satisfactorily represented by formulæ based on physical considerations.

Time observations were taken on 135 nights, and the meteorological work has been carried on as in former years.

Liverpool Observatory.

No material alteration has been made in the routine work of the Observatory, and the instruments remain much in the condition mentioned in the last report. A Richard self-recording thermograph of the largest size was mounted last summer. This instrument completes the apparatus for the automatic registration of meteorological elements. A second bifilar pendulum on the principle suggested by Professor G. H. Darwin has been mounted in the basement, the plane of whose registration is turned 90° in azimuth from the one earlier mounted and mentioned in the last annual report. The results derived have been up to the present very disappointing, and owing to the bursting of a water-pipe in

the cellar they have had to be discontinued. Within the last few weeks a Milne seismometer has been placed in the same cellar (under arrangements made with the Earthquake Committee of the British Association), with the view of determining the character of the geological formation best adapted for the record of earthquake disturbance. It is proposed to compare the results of the daily waves shown by this instrument with those obtained by the Darwin bifilar. The Milne seismometer has been in operation only since the beginning of the year.

The alteration made in the method of firing the one o'clock gun, to which allusion was made in the last report, has proved quite satisfactory. There has been no failure of the signal during the year, and only on a very few occasions has the error in time amounted to half a second. The transit instrument has performed satisfactorily and has been employed in the same manner as last year. Owing to bad weather and the small altitude of the planets *Jupiter* and *Saturn*, the measurement of diameter has been discontinued. Some observations of the diameter of *Venus* with various micrometers have been made. Such cometary observations as have been made will, as usual, be submitted to the Society for publication. A continuous look-out was kept for the *Leonids* at the time of their possible reappearance. The sky was generally overcast on the three nights most suitable for observation, and no results of any value were obtained. The reduction of an occultation of the *Pleiades* and of stars at times of two recent eclipses of the Moon has been made by Mr. Henry Plummer, and the results have been published by the Society.

Radcliffe Observatory, Oxford.

This year a determined effort has been made to overtake the arrears of reduction and publication to which the present Director of the Observatory succeeded, and for this purpose systematic observations have been interrupted during the greater part of the year.

During the year the Meteorological Results from 1892 to 1899 inclusive have been prepared for press, and are now in the printer's hands. They will shortly be published as the forty-eighth volume of the *Radcliffe Observations.*

The reductions of the astronomical observations, which were also very much in arrears, have been vigorously pushed forward, and are now in a fairly satisfactory condition.

For the Right Ascensions, the means of all transits have been taken, and the reduction to the centre wire completed to 1900 July. The instrumental errors have been determined, and the corrections entered to 1899 November 17, and the corrections applied to 1896 March 2.

All the observations of zenith distance have been entered to the end of 1900, and, with the exception of the planetary observations, are completely reduced to 1898 December 6.

No further progress has been possible in the reduction of the old observations of Dr. Hornsby and his successors, between the years 1774 and 1838, which were mentioned in last year's Report, and of which some specimens were published in the *Monthly Notices* for 1900 January. An application was made to the Government Grant Committee of the Royal Society for a grant of money to enable this work to be undertaken; but the application was unsuccessful, being postponed on account of the large sum (2000*l.*) which will be needed for its complete accomplishment. The period, 1774, at which these observations begin, brings us back to within twelve years of Bradley's time, while, in point of accuracy, these observations seem to be quite equal to his.

It will be a serious loss to astronomical science if these valuable old observations are, for want of funds, allowed to perish unused.

In the early part of the year a good deal of time was devoted to an examination of the new micrometer and breech-piece of the transit-circle mentioned in last Report. In its original form, no accurate results could be obtained with this micrometer. Certain alterations and improvements were found to be necessary, and these were effected by Mr. Simms in February and April. It is still necessary, however, to be careful in the use of this instrument.

In September, the sidereal clock was sent to Messrs. E. Dent for the insertion of a new contact wheel, the previous one supplied by them having been found to be slightly eccentric. This alteration has much improved the running of the clock and the registration of the clock beats on the chronograph.

During the year an attempt was made to determine the errors of the pivots of the transit-circle by means of an apparatus specially designed for that purpose. This consisted of a flat mirror of five inches diameter attached to the west pivot and rotating with it. To this was directed a fixed collimator with cross-wires in its focus. Unexpected difficulties have been met with in these experiments, and the results are not yet quite satisfactory. The experiments are still in progress.

The Barclay Equatorial has been used for observations of variable and coloured stars, for the examination of some nebulæ and clusters, for the partial eclipse of the Sun on May 28, and for the occultations of *Saturn* by the Moon, which occurred on June 13 and September 3. Some of the results of these observations have been already communicated to the Society, and published in the *Monthly Notices*.

The heliometer and Marlborough telescope were also employed for observing the eclipse of the Sun on May 28, and the occultation of *Saturn* on September 3.

The result of the watches kept at this Observatory for *Leonids* on November 13–16 has already been communicated to the Society.

The meteorological observations and automatic registrations have been maintained as usual during the year.

The five underground platinum-resistance thermometers have worked very satisfactorily. The observations obtained with these instruments during the year 1899 have been fully discussed, and the results published in the *Transactions of the Royal Society* (Vol. 195, pp. 235–258), in a memoir entitled *Underground Temperatures at Oxford in the year* 1899, *as determined by five Platinum-resistance Thermometers.*

Satisfactory progress has been made during the year with the large equatorial refracting telescope, which, as was mentioned in last Report, it has been decided to erect at this Observatory.

The 18-inch visual object-glass, which the instrument is to carry, has been finished, and the 24-inch photographic object-glass is very nearly so. The mechanical parts have all been constructed, and the instrument is now in process of erection in Sir Howard Grubb's workshop. The construction of the elevating floor is also well advanced.

At Oxford a new tower, 35 feet high and 31 feet in internal diameter, has been built; the dome of steel and *papier-mâché* has been erected, and the water laid on for the hydraulic ram.

It is hoped that the erection of the telescope at Oxford may be commenced early in the spring.

University Observatory, Oxford.

The work for the *Astrographic Catalogue* went on steadily through the first eight months of the year, but the last four months have been devoted almost entirely to work on the planet *Eros*. Hence the number of plates completely reduced during the year is smaller than usual, being 103, which brings the total to 749 plates out of the 1180 required. Besides these, about 45 plates are measured and the reductions in a forward state. It may be remarked that the zones $+25°$ $+26°$ $+27°$ are now finished. The number of measures made during the year (in addition to those on *Eros* plates) was 63,000.

With regard to *Eros*, 85 plates, containing in all 553 exposures, have been taken, the exposures being almost always near the extremes of the parallactic range. The usual exposures have been 1^m, 2^m, or 3^m, though others have been made by way of experiment from 10^s to 10^m. On December 28, when the parallax was $27''\cdot9$, 54 exposures were made between hour angles $1^h\ 38^m$ east and $7^h\ 58^m$ west; but the weather near the time of greatest parallax was not generally good.

Standard coordinates have been computed for the stars on these plates which are in the catalogues of the *Astronomische Gesellschaft* (Bonn, Harvard, Leiden, &c.), involving 1184 positions up to December 22. These stars and the planet have been measured in a provisional manner (which may be supple-

mented later) on 27 plates, involving 12,665 measures. The positions of the planet derived from five of these plates were published in November (*Monthly Notices*, vol. lxi. p. 16).

A good deal of work in the measurement of eclipse photographs has been done by the director, and some of it is ready for publication. The law of coronal brightness seems to be that of the inverse sixth power of the distance from Sun's *centre*.

The director observed the eclipse of May last at the Algiers Observatory, as one of the observers sent out by the Joint Permanent Eclipse Committee.

A new dome was supplied for the Astrographic Equatorial by Messrs. T. Cooke & Sons, during the spring, with a wide shutter opening ($4\frac{1}{2}$ feet to $7\frac{1}{2}$ feet) which has been an immense convenience. The *Eros* work could scarcely have been done at all with the old dome. During the four months when the dome was being erected, and the supply of plates to be measured ran short, a good deal of experimental work was done in comparing our measures with the Bonn *Durchmusterung* by the method indicated in *Monthly Notices*, lx. p. 427. It seems, however, doubtful whether this comparison is profitable, as the D.M. places are found to be too rough to give any results of value.

Temple Observatory, Rugby.

The usual educational work has been carried on as before, the early part of each fine evening being given up to boys. There have been special classes during the October term for instruction in the use of the instruments. The measurement of double stars has been continued later in the evenings. The Observatory has suffered much in the regretted loss of Mr. Atkinson, whose health unfortunately failed.

Stonyhurst College Observatory.

The solar surface drawings number 157 on as many days. The number is smaller than usual, owing mostly to building alterations of the dome, which kept the telescope idle from April 2 to May 14. The mean spotted disc-area deduced from these drawings is 0·55, against 0·74 of last year.* It is not yet clear whether we have arrived at, or passed, the minimum epoch; and there is the same uncertainty about the minimum epoch of magnetic disturbance. Taking the extreme range of the declination magnet on each day as a measure of the magnetic disturbance on the day, the mean of these for the year is $9'{\cdot}7$, against $12'{\cdot}9$ for the preceding year. But a small spot group was sketched on September 2 and again on September 3, in latitude $-25°$ and longitude $105°$; and this

* The unit being $\frac{1}{5000}$ of the visible disc.

appearance in high latitude, according to past experience, may be the forerunner of the expected revival of solar surface activity.

The work, which was commenced last year, of comparison between individual sun-spots and Earth-magnetic storms, was brought to a conclusion in September; and the results were presented to the R. A. S. in a paper read at the December meeting. This will appear in the next volume of the *Memoirs* of the Society; an abstract of the same is given in the December number of *The Observatory*. The comparisons cover the eighteen years from 1881 January to 1898 December, during which period we have a daily record of the Sun's surface in the Greenwich volumes, from photographs taken at Greenwich, at Dehra Dûn, India, and at the Royal Alfred Observatory, Mauritius.

The tabulations occupied a considerable part of the past year and the early months of this year, 1900. They contain complete histories of the principal spots from first appearance to final extinction; and in this form they have been found of great service both for the comparison between sun-spots and magnetism, and for the study of characteristic differences between separate spots, and between the same spots at different ages. The latter study was undertaken by Fr. Cortie; and his conclusions are given in the May number of the *Monthly Notices*, in a paper "On the Greater Sun-spot Disturbances for the years 1881–99," and "On the Types of Sun-spot Disturbances," in a paper read at the meeting of the British Association in Bradford in September.

The tabulations of magnetic storms has also led to a special study of these independently of their connection with sun-spots. Comparative measures of their magnitude at different positions on the Earth's surface have been commenced, and fair progress has been made; but the work will need considerable time.

The watch for the *Leonids* was kept throughout the night of November 14–15, when it was mostly clear; but very few meteors were seen. The nights 12th and 13th were cloudy throughout.

During the progress of the solar eclipse of May 28 the solar prominences were measured with the spectroscope; and the time of last contact was observed satisfactorily. These were communicated to the R. A. S. in June, and are published in that number of the *Monthly Notices*.

The Grating Spectrographs of the H K region of the solar spectrum number 57. The instrument has been partly dismounted since the end of October, in order to make use of its quartz lens telescope in connection with some experiments in stellar spectrography. These experiments have occupied all the available nights of November and December. They are not yet complete; for progress is slow on account of the many photographs required, and the few clear nights. At present they promise well to be a valuable addition to the spectrographs already obtained, by a considerable extension of the spectra in the ultra-violet region.

Markree Observatory (Col. E. H. Cooper's).

During the year 1900 the Observatory has continued under the charge of Mr. F. W. Henkel, B.A., as before.

The usual meteorological observations have been regularly made and reduced, the weekly and monthly returns having been sent to the Meteorological Office, the Registrar-General at Dublin, and Mr. Symons as before. A few observations have been made with the unifilar magnetometer and the dip circle.

The partial eclipse of the Sun on May 28 was well seen and the time of last contact determined. A watch made for the *Leonids* on three nights had almost negative results, only one or two being seen on the early morning of November 17.

A few lectures were given in the early part of the year, and it is proposed to give some more should sufficient interest exist for them. Astronomy, however, is a subject not likely to be taken up by the Technical Education Committee.

Mr. E. Crossley's Observatory, Bermerside, Halifax.

During the past year the 9-inch equatorial has been used for observations of *Jupiter* and measures of binary stars; and the usual observations for time have been made with the transit instrument.

Meteorological observations have been recorded at 9 A.M. and 3 P.M. as in past years, and the usual reports have been sent to Mr. H. Sowerby Wallis, the Registrar-General, and others.

Wolsingham Observatory (Rev. T. E. Espin's).

The $17\frac{1}{4}$-inch has been used during the year for making micrometrical measures of double stars between N. decl. 30° and 60° which have been for the most part neglected. A working list of upwards of 900 stars was prepared early in the year, partly from vol. xl. *R.A.S. Memoirs*, and from the various volumes of the catalogue of the *Astron. Gesellschaft*, and the places for convenience of identification reduced to 1855. Observations were made on 65 nights during the year. The total number of measures made is 2811; 284 stars have been measured on one or more nights. The measures of 83 have been completed, and, together with the measures of 39 new double stars, have been prepared for the press.

Sir William Huggins's Observatory, Upper Tulse Hill.

The photography of the spectra of stars and of nebulæ which has been in progress for some years has been continued during the past year.

Experiments in the laboratory in connection with the observatory work are also in progress.

Rousdon Observatory, Lyme Regis, Devon (Sir Cuthbert E. Peek's).

The building and equipment of the Observatory have been maintained in their usual order. February and March were two very cloudy months, but the rest of the year was generally favourable, and observations were made on 175 nights, which is somewhat above the average. The 6·4-inch Merz equatorial has been kept at the regular observation of long-period variable stars; Argelander's method was followed, as during the previous fourteen years. Five hundred and fifty-nine magnitude determinations have been made. At each observation the light of the variable is estimated relatively to five comparison stars in the same field. Thus, during the year 1900, about 3350 observations of stellar brightness have been made. Twenty-one maxima and thirteen minima have been observed. About twenty-five variables of long period are under regular observation; and these being mostly circumpolar, the light variations are continuously recorded.

Variable Star Notes No. 6 has been published and distributed. This contains observations of *T Cassiopeiæ* for the ten years 1889 to 1898, and of *R Cassiopeiæ* for the twelve years 1887 to 1898. The results are given concisely in tabular form, accompanied by diagrams of the light curves. Other instalments of the work are far advanced and will appear shortly.

Transits of stars have been taken as often as required for the timing of the sidereal clock, which has maintained a very steady rate.

The occultation of *Saturn* was observed under very favourable conditions on September 3. The planet disappeared behind the Moon's dark limb without the slightest distortion; at reappearance the very faint and feeble light of the planet was in strong contrast to the great brilliancy of the Moon's bright limb.

Dr. Isaac Roberts's Observatory, Crowborough Hill, Sussex.

The work of photographing star clusters and nebulæ, which has always been the chief feature of this Observatory, has been steadily pursued during the past year. A list of objects photographed in that period is given below, in the same form as that adopted in previous years.

Preparation was made to photograph the trails of any Leonids that might be caught near the radiant point, if the expected "shower" had occurred. However, though close watch was kept for several nights, at the predicted time, so few meteors were seen that no attempt was made to expose plates.

List of the principal Photographs taken in 1900.

	R.A. h m	Decl. ° ′	Expos. h m
Star magnitudes near γ Pegasi	0 8	+14 38	1 30
♅'s Nebulous Region No. 1	0 10	+ 9 26	1 30
" " " " 4	0 25	+ 3 59	1 30
" " " " 5	0 30	+23 25	1 30
Neb. M. 31 Andromedæ	0 37	+40 43	1 30
♅'s Nebulous Region No. 8	0 39	+39 16	1 30
" " " " 9	0 41	+43 30	1 30
" " " " 10	0 48	+43 35	1 30
Neb. ♅ I 151 Piscium	1 19	+ 9 1	1 0
Neb. M. 33 Trianguli	1 28	+30 9	1 30
Neb. M. 74 Piscium	1 31	+15 16	1 30
Minor planet *Eros*	1 32	+45 13	1 0
Neb. M 76 Persei	1 36	+51 4	1 30
♅'s Nebulous Region, No. 11	1 41	+29 48	1 30
" " " " 12	2 28	+19 0	1 30
Neb. M. 77 Ceti	2 37	− 0 26	1 0
Cl. ♅ VI. 25 Persei	3 7	+46 51	1 30
Cl. M. 79 Leporis	5 20	−24 37	1 0
Nebulæ near ζ Orionis	5 37	− 2 10	2 15
Cl. M. 35 Geminorum	6 2	+24 21	1 30
Nebulæ in Monoceros	6 25	+10 0	2 47
Neb. ♅ IV. 3 Monocerotis	6 27	+10 14	1 30
Neb. ♅ IV. 2 Monocerotis	6 33	+ 8 50	1 30
Cl. M. 41 Canis Majoris	6 42	−20 38	1 0
Cl. M. 93 Argûs	7 40	−23 37	1 0
Neb. ♅ I 204 Lyncis	8 36	+50 35	1 30
Neb. ♅ IV. 66 Ursæ Majoris	8 51	+54 11	1 30
Nebulæ M 81, 82 Ursæ Majoris ...	9 47	+69 50	1 30
Neb. ♅ IV. 48 Leonis Minoris ...	9 57	+41 15	1 30
Neb. ♅ IV. 10 Leonis...	10 19	+17 41	1 30
Neb. ♅ IV. 60 Ursæ Majoris	10 32	+54 3	1 30
Nebulæ ♅ I. 116, 117 Leonis Minoris...	10 44	+33 33	1 30
Neb. ♅ I. 225 Ursæ Majoris	11 16	+59 39	1 30
Neb. ♅ I. 20 Leonis	11 19	+11 55	1 30
Neb. ♅ I. 219 Ursæ Majoris	11 19	+39 21	1 30
Neb. ♅ I. 131 Crateris...	11 19	− 9 13	1 30
Neb. ♅ I. 21 Leonis	11 35	+12 4	1 30
Neb. ♅ I. 82 Ursæ Majoris	11 44	+27 35	1 30

	R.A. h m	Decl. ° ′	Expos. h m
Neb. ♅ I. 67 Crateris	11 49	−13 24	1 30
Neb. ♅ IV. 28 Corvi	11 56	−18 17	1 30
Neb. ♅ I. 174 Comæ	11 58	+32 29	1 30
Neb. ♅ I. 175 Comæ	12 10	+33 47	1 30
Neb. M. 99 Virginis	12 14	+14 58	1 0
Neb. ♅ IV. 5 Virginis	12 28	+ 0 39	1 30
Nebulæ ♅ IV. 8, 9 Virginis	12 31	+11 50	1 30
Neb. ♅ IV. 30 Canum Venaticorum ...	12 54	+35 26	1 30
Neb. M. 51 Canum Venaticorum ...	13 25	+47 43	1 0
Neb. M. 101 Ursæ Majoris	13 59	+54 50	2 45
Cl. M. 12 Ophiuchi	16 42	− 1 46	1 30
Cl. M. 10 Ophiuchi	16 52	− 3 56	{0 50 1 30
Cl. M. 23 Ophiuchi	17 51	−19 0	1 0
Cl. M. 18 Clypei	18 14	−17 11	0 41
Star mags. near η Serpentis	18 20	− 2 55	1 30
Neb. ♅ IV. 16 Delphini	20 18	+19 47	1 0 (two)
Neb. ♅ IV. 76 Cephei	20 33	+59 48	1 30
Neb. ♅ I. 192 Cephei	20 57	+54 10	1 30
Cl. M. 15 Pegasi	21 25	+11 44	1 0
Cl. M. 30 Capricorni	21 34	−23 39	1 30
Region of *nova* Cygni	21 38	+42 24	2 0
Neb. ♅ I. 55 Pegasi	23 0	+11 47	2 50
♅'s Nebulous Region No. 52	23 0	+29 17	1 30

Daramona Observatory (Mr. W. E. Wilson's).

During the early part of the past year experiments were made with different coloured screens, with the idea of photographing the corona at the total solar eclipse on May 28. After some experiments with a screen stained with picric acid, one stained with tartrazine was found to be the most suitable. This was placed in close contact with a Lumière plate which was sensitive to the green part of the spectrum. The 6-inch O.G. was used in conjunction with a fine cœlostat made by Sir H. Grubb, and placed at the disposal of the Director by the Royal Dublin Society. The eclipse was observed at Plasencia in Spain in perfect weather.

In August a Callendar's electric recorder was obtained, for recording the daily amount of solar radiation. A series of experiments were made with different forms of receivers, and the results compared with those of Ångström's pyrheliometer which

measures the amount of radiation in absolute electric units. A new type of receiver has been ordered from the Instrument Company at Cambridge, and will be tried during the present year. Some preliminary experiments were made in the laboratory on the bearing of the laws of radiation on our estimate of the temperature of the Sun. They will shortly be resumed again.

A new breech-piece has been made for the 24-inch reflector by Sir H. Grubb, on the same design as that of the Crossley reflector, and it is hoped that it will give better photographic results than the old one.

The weather during the past year has been the worst on record; in fact, no work was done during the latter half of the year.

Kodaikánal and Madras Observatories.

During 1900 the astronomical work at the Kodaikánal Observatory has been almost entirely preliminary. The buildings are not yet completed, but are now far advanced, and regular observations should be begun early in 1901. Meanwhile regular meteorological and actinometric observations are being made.

At Madras the observations are confined to those necessary for maintaining the regular time service and the meteorological records.

The *New Madras General Catalogue* was distributed early in the year.

Sydney Observatory.

A change in the astronomical staff will make it possible to go on rapidly with the meridian observations required for the photographs of our zone of the heavens. On 1900 March 28 Mr. Sellors retired from his position in the Observatory to accept a position in the computing staff of the Trigonometrical Survey. The vacancy in the Observatory staff was filled on 1900 June 11 by the appointment of Mr. W. E. Raymond, who had for years been assistant to the Chief Surveyor in the Trigonometrical Survey. There Mr. Raymond had a long experience of meridian work in the field, and took up his work of observation and computing at the Observatory without delay. Two junior computers were also added to the staff, and I anticipate a comparatively rapid progress in our meridian work. There has not been any other change in the staff.

Observations.—

1498 zone stars.
704 clock stars.
167 azimuth stars.
858 determinations of collimation and azimuth.

The Sun has been observed regularly for the time ball.

All computations consequent upon these observations are in a very forward condition, the zone stars being nearly complete.

Red Hill Photographic Work.—Mr. Short has obtained satisfactory results in number and quality of work, the results being better and more numerous than those obtained in Sydney.

Plates taken : 175 chart plates.
323 catalogue plates.
102 test plates.

Measurements of Star Plates.—The joint work (Melbourne and Sydney) has been carried on vigorously. A full report of this work will be published later.

We have two of the measuring machines designed by Sir David Gill, and one near completion, which will give the measures direct in minutes and seconds of arc; it is hoped that it will be rapid and easy to work.

The Library.—During 1900 993 books and pamphlets have been received in exchange. This is 30 per cent. more than in the previous year.

Time Service.—Time balls at Sydney and Newcastle (the latter place 60 miles distant) have been satisfactorily dropped every day.

Lovedale Observatory, Cape Colony (Dr. A. W. Roberts's).

The work of this Observatory has been, as in former years, the observation of variable stars south of decl. $-30°$.

As it was not possible fully to overtake all the work, many short period variables, especially those whose periods have been already rigorously determined, were dropped during the year.

The observations made are as follows :—

	Stars.	Observations.
Algol variables	6	481
Rapid variables	2	295
Short period variables	6	360
Long period variables	70	2476
Suspected variables	6	50
Total	90	3662

The new prismatic equatorial by Cooke arrived at the close of the year.

The instrument has been specially designed and constructed for the observation of variable stars brighter than the tenth magnitude, and also for the projected magnitude survey of the southern heavens.

In front of the object-glass and rigidly bolted to the tube of the telescope is a large prism of clear glass. The telescope tube

rotates in a cradle, and thus the field under observation can be placed in any position. A dial in front of the eyepiece indicates the amount of rotation.

The eyepieces give a large field, the lowest power having a clear diameter of 3°.

The object-glass, which is 2 inches diameter, can be stopped down to any size.

The telescope and its accessories, a dome and transit-room and a sidereal chronometer, is the generous gift of Sir John Usher, of Norton, Midlothian. Lord McLaren personally interested himself in the construction and fittings of the instrument.

Mr. Tebbutt's Observatory, The Peninsula, Windsor, New South Wales.

The observations were from various causes not so numerous as in previous years, and were made chiefly in the winter months. The following is an abstract of the work :—

Meridian Department.—

Nights on which the time was determined	... ...	83
Observations of stars with a declination not exceeding 40°	...	423
Observations of stars in high declination for azimuth ...	...	107
Separate determinations of	level error	241
	collimation error	24
	azimuth error	75

Extra-Meridian Department.—The following comparisons of planets were made with the filar micrometer on the 8-inch equatorial :—

	Nights of Observation.	Number of Comparisons.	Number of Comparison Stars.
(1) Ceres	23	317	9
(3) Juno	8	96	6
(6) Hebe	13	189	4
Jupiter and β^1 Scorpii	5	92	1

There was no comet well placed for observation. A careful but unsuccessful search was made on three nights for Brorsen's Comet, in accordance with an ephemeris forwarded by Dr. Kreutz. A search was also made for Giacobini's Comet, in accordance with the first cable message, which erroneously represented the right ascension as increasing. An amended message was subsequently received, but cloudy weather and strong moonlight combined to prevent further search.

The occultation of *Jupiter* and his satellites was well

observed on September 29. Observations of twenty-seven phases of lunar occultations of stars, and of some of the phenomena of *Jupiter's* satellites, were also made. Twenty-five pairs of the most interesting southern double stars were likewise repeatedly measured with the 8-inch equatorial, and the usual meteorological observations attended to. The whole of the observing and reducing work was executed by the proprietor himself.

Notes on some Points connected with the Progress of Astronomy during the Past Year.

Discovery of Minor Planets in 1900.

Fifteen new planets were discovered during the past year, as follows :—

Provisional Designation.	Permanent Number.	Date of Discovery, 1900.	Discoverer.	Place of Discovery.
FA	453	Feb. 22	Charlois	Nice
FC	454	March 28	Schwassmann	Heidelberg
FE	...	„ 6	Hirayama	Japan
FF	...	„ 6	„	„
FG	455	May 22	Wolf—Schwassmann	Heidelberg
FH	456	June 4	„	„
FJ	457	Sept. 15	„	„
FK	458	„ 21	„	„
FL	...	„ 26	„	„
FM	459	Oct. 22	„	„
FN	460	„ 22	„	„
FP	461	„ 22	„	„
FQ	462	„ 22	„	„
FS	463	„ 31	„	„
FU	...	Dec. 20	„	„

To these should be added the following planet, discovered in 1899, but not announced till after the last Annual Report :—

FD	452	1899 Dec. 31	Keeler	Lick Obs. (Mt. Hamilton)

The planets provisionally designated FB, FO, FR, FT were found to be identical with (117) *Lomia*, (244) *Sita*, (177) *Irma*, (220) *Stephania*. The identity of FT is, however, not absolutely certain. Planet FQ (462) is identical with the planet DD, discovered in 1896, but not numbered at that time.

The following planets, discovered in 1899, but not numbered at the date of the last report, have since received permanent numbers: ER, 446; ES, 447; ET, 448; EU, 449; EV, 450; EX, 445; EY, 451.

The planets provisionally designated EO, FE, FF, FL do not receive permanent numbers, not having been sufficiently observed.

The following planets have been named: (353) *Ruperto-Carola*, (371) *Bohemia*, (386) *Siegena*, (440) *Theodora*, (444) *Gyptis*, (445) *Edna*.

Of the planets enumerated in the last report as having been observed at one opposition only, the following have since been observed at a second opposition: 220, 328, 382, 388, 425, 432. Special search was also made for 285 and 406, but without success.

The present very favourable opposition of *Eros* is being fully utilised for a new determination of the solar parallax. A conference was held in Paris in July to decide on the best methods of combined work. Upwards of fifty observatories are co-operating, the great majority by photography, though a few astronomers, among whom may be mentioned Professor Barnard with the 40-inch Yerkes equatorial, are making visual micrometric measures. Observatories taking part in the astrographic chart are in most cases devoting their 13-inch equatorials to this work.

During the earlier part of the opposition when the planet was in very high north declination, and southed about midnight, the diurnal method of finding its parallax was the most convenient. Exposures were made as soon as possible after sunset, and again as long as possible after the meridian passage, so as to obtain the maximum displacement. Now that the planet souths early in the evening, and is rapidly moving south, the method of nearly simultaneous observations at two observatories widely separated in latitude will be more suitable.

The Paris Committee has prepared a list of several hundred reference stars of the ninth magnitude or brighter, of which several will appear on each plate and will enable the plate constants to be determined. These stars are being observed on the meridian at several observatories. It is remarked that in practice it may be necessary to compare the planet with fainter stars (say down to the 12th magnitude) lying nearer to it; the photographs will give the means of obtaining the places of these stars with accuracy. An exposure of 6 minutes is found sufficient to record them.

As observations have accumulated, Signor Millosevich has published several successive emendations of the elements of the orbit. The following are his latest elements, based on the observations of the first opposition, combined with a few selected ones at the present opposition; they will of course be liable to further alteration when all the observations now being

made are reduced and discussed, but such alteration will be very small.

Epoch and Osculation.	1898 Aug. 2·5, Berlin M.T.		1900 Oct. 31·5, Berlin M.T.	
M	205° 21′ 43″·0		304° 24′ 44″·7	
π	121 10 55·3	1900·0	121 9 51·8	1900·0
ω	177 39 3·6		177 39 6·2	
☊	303 31 51·7		303 30 45·6	
i	10 49 35·4		10 49 39·0	
ϕ	12 52 21·2		12 52 47·3	
μ	2015·2730		2015·2372	
$\log a$	0·1637818		0·1637869	

Perturbations by *Venus*, the Earth, *Mars*, *Jupiter* and *Saturn* have been applied (*Ast. Nach.* 3678).

We now know the mean motion with sufficient accuracy to form a forecast of the most favourable oppositions of the coming century. It is clear that an opposition is more favourable in proportion as the interval is smaller between the planet's perihelion passage and the Earth's passage through the longitude of the planet's perihelion. This interval is tabulated for all the years in the century for which it falls below 24 days.

Year.	Interval in Days.	Year.	Interval in Days.
1901	17·42	1945	23·53
1923–24	23·24	1968	17·13
1931	7·65	1975	1·54
1938	7·95	1982	14·05

It will be seen that there is no opposition more favourable than the present for 30 years, and that there are only five more favourable ones in the century.

In the above investigation μ is taken as $2015''\cdot255$, and perturbations, both secular and periodic, have been neglected.

Mr. Henry Norris Russell has made some computations on the perturbations of *Eros* by the Earth and *Mars* (*Ast. Journ.* 483, 484).

The perturbations by the Earth in mean longitude include the term $+747''\sin(7g-4g')$, where g, g' are the mean anomalies of *Eros* and the Earth; the period of this term is 41·24 years, and the whole range in the resulting shift in the place of *Eros* as seen from the Earth is nearly 3^{c}. This will thus in time give a very accurate determination of the solar parallax.

The following are the principal perturbations in mean longitude produced by *Mars*.

Coefficient.	Period in Years.	Coefficient.	Period in Years.
1″69	27·4	11″59	40·8
9·42	13·7	22·81	78·0
1·59	9·1	11·85	85·5
2·37	16·2	35 (?)	890 (?)

The last term is very uncertain, and cannot be accurately determined for at least 15 years. But Mr. Russell considers that the other terms may in time give a value of the mass of *Mars* even more reliable than that deduced from the satellites.

A. C. D. C.

The Comets of 1900.

The number of comets discovered in the last year has been small, and the objects themselves have generally been faint and uninteresting. The dearth of interest has been further accentuated by the passage of several periodic comets through perihelion without observation.

On January 31 M. Giacobini discovered a faint comet in the constellation *Eridanus* on its way to perihelion passage. The comet was a faint object, and on February 5 it was described as very faint and difficult to observe in a 16-inch telescope. This small brilliancy remained fairly constant for two or three months, the comet, however, being too near the Sun in April for observation. Owing to its rather large perihelion distance, it remained outside the Earth's orbit, and in July came into opposition, when, owing to its proximity to the Earth, it appeared much brighter than at the date of discovery. Professor Howe, of Denver, recovered the comet on May 27, after its perihelion passage. Assisted by a considerable northern declination, observations were fairly easy onwards throughout July, but the comet grew rapidly fainter in the autumn. The observations are fairly well represented by a parabola, but the definitive orbit is not yet known.

The second comet of the year was independently discovered by M. Borrelly and Mr. Brooks, of Geneva, U.S.A., on July 23, the former astronomer having the priority by about five hours. The object proved to be a fairly bright telescopic comet, having a tail estimated at a degree in length, but it never became visible to the naked eye. Mr. Brooks reports that soon after discovery two faint branches or auxiliary tails were detected, one upon each side of the main tail. Although the principal tail became much fainter as the comet receded from the Sun, it nevertheless maintained its original length of about one degree. The diminution of brilliancy noticed by Mr. Brooks was tolerably rapid, and at the end of September it had scarcely one-thirtieth of the lustre at the time of discovery. No suspicion of ellipticity attaches to this orbit.

The third and last cometary discovery of the year is likely to prove the most interesting. This object was first seen by M. Giacobini on December 20 in 22° S. declination. The comet was moving slightly northwards, and this circumstance may somewhat favour observation, which, it is to be hoped, will be continued as long as possible, since the orbit will beyond doubt prove elliptical. The first approximate elements showed some resemblance to those of 1857 IV., to which Dr. A. Möller assigned an orbit of 234·7 years, founded, however, on but little more than two months' observations. Elliptic elements deduced by Dr. A. Kreutz, without any assumption as to the eccentricity, give the more ordinary period of about $6\frac{3}{4}$ years, and the orbit bears considerable resemblance to those of Wolf and of Barnard (1892 V.). The comet appears to have been in perihelion early in December, and is now rapidly growing fainter. It may be observed till the beginning of March, when, however, it will possess a brilliancy of only one tenth that of discovery; and this, coupled with an unfavourable position in the sky, will render observation very difficult.

Among the comets which have returned to the Sun without being seen is Finlay's Comet of 1886, an object especially interesting from its suspected connection with Lexell's Comet. M. Schulhof has made a most elaborate discussion of the motion of this comet, and, notwithstanding the extreme improbability of its being seen, circulated an accurate ephemeris to assist its discovery, though he recognised the hopeless character of the search. The comet has not been seen owing to its faintness and closeness to the Sun, but at the next return, in 1906, the conditions are very favourable, since the comet approaches the Earth within 0·2 R. On its next journey the least distance between the comet and *Jupiter* will be 0·5 R., and the elements will suffer considerable alteration.

Comet 1894 IV., discovered by Mr. E. Swift, and having a period of 5·855 years, has also passed without detection. This comet is possibly identified with the lost comet of De Vico. Mr. F. H. Seares circulated, but without success, an ephemeris extending from July 23 to December 30, based on a rigorous determination of the orbit. The theoretical brilliancy of the comet showed the hopelessness of the search. In 1894 the comet was seen with great difficulty, and at this return the brilliancy was only one-ninth of what it then possessed. This comet seems to have undergone considerable perturbation, for the date of the perihelion passage, neglecting disturbances, was 1900 August 20, but the complete calculation made the date 1901 February 13.

Another comet which has been sought unsuccessfully is that of Barnard. A most patient search was made by Dr. Schwassmann, of the Königstuhl Observatory, Heidelberg, by means of photography. Some twenty-five photographs were taken on nineteen nights, with an average exposure of two hours, each

plate covering an area of 100 square degrees. The portions of the sky photographed were determined by an ephemeris supplied by M. Coniel. No trace of the comet was found, however, while stars of the thirteenth magnitude impressed themselves on the plate. This comet was not seen on the occasion of its last return in 1894–5, and the error of the date of the perihelion passage, fixed for October 28, may amount to as much as two or three weeks. The chances of its future recovery therefore by means of ephemerides are very remote.

To this list must probably be added Brorsen's Comet, which attained its greatest brilliancy at the beginning of this year.

W. E. P.

Progress of Meteoric Astronomy in 1900.

January Meteors.—Prof. A. S. Herschel, at Slough, watched for the return of the *Quadrantids* on January 2, during the $5\frac{1}{2}$ hours from 11^h to $16\frac{1}{2}^h$. The number of meteors seen was 130, of which the paths of 80 were registered. About 29 of the latter belonged to the special shower of the epoch, while the remainder were furnished by radiants in *Boötes*, *Draco*, *Hercules* and *Ursa Minor*. Mr. W. E. Besley, at Clapham Common, S.W., also obtained an observation on January 2, between $11^h\ 38^m$ and 13^h, and counted 30 meteors nearly half of which were *Quadrantids*. At $11^h\ 59^m$ he recorded a 1st mag. meteor which was also noted by Prof. Herschel, at Slough. An observer at Chalfont, Buckinghamshire, reports that on January 3, 6^h to $6^h\ 30^m$ A.M., he noticed "several fine shooting stars which had tails and burst like rockets." Mr. R. Service, at Dumfries, states that on January 4, between 6 A.M. and daylight, he counted more than 30 very fine meteors, hardly one being under 1st mag. The prevailing colour was yellow.

April Meteors.—Prof. Herschel found meteors very rare on the evenings immediately preceding the *Lyrid* display, only 7 being recorded during 7 hours' watching on April 15, 16, 17, and 18. On later nights there was a marked increase; on April 19 he noted 12 meteors in $4\frac{1}{2}$ hours, on April 20, 25 meteors in 5 hours, and on April 21, 35 meteors in $4\frac{1}{2}$ hours. There were about 15 *Lyrids* with pretty rich outlying radiants in *Draco* ($261°+48°$), and *Lyra* ($280°+47°$). Observations were also made by Mr. A. R. Hinks, Cambridge, A. King, Leicester, and others, but meteors generally were scarce and the *Lyrid* shower offered very feeble evidence of its presence.

May Meteors.—Several observers in England awaited the return of the *Aquarids* on the morning of May 4, and a few of these bright, long-pathed meteors were observed. But the position of the radiant is unfavourable to the shower's observation in high northern latitudes. That it returned pretty actively is certain, for the Rev. J. T. Bird noticed it in South Africa. While bivouacking on the veldt, on the morning of May 3, he observed

a small shower of swift meteors with streaks radiating from somewhere between *Altair* and *Fomalhaut* (*Journal of the B.A.A.*, vol. xi. p. 32). A conspicuous meteor of this shower with a very long path and streak was seen by Prof. Herschel, at Slough, and by Mr. J. H. Bridger, at Farnborough. The real path works out satisfactorily from the pair of observations and it is included in Table II. This is the first *Aquarid* of the May epoch of which the heights &c. have been deduced. The computed velocity of 28 miles per second is much slower than the theoretical speed of 41 miles per second.

July and August Meteors.—There was a full moon near the period of the maximum of the *Perseids*, and the principal observations were effected this year during the last half of July. Meteors were tolerably numerous, and the *Perseids* were in evidence on and after July 19. The richest of the minor showers was formed, as usual, by the δ *Aquarids*. Several early *Perseids* were recorded at two stations and the positions of their radiants show the motion of the *Perseid* centre very distinctly. In presence of moonlight on August 10 there were few meteors, but on August 12, when the atmosphere was very clear, a fair number of *Perseids*, including some brilliant specimens, were observed. Several large fireballs appeared in July and August and were well seen; their real paths are given in Table II.

October Meteors.—The *Orionids* were fairly active on October 23, but the strongest shower of that date appeared to be from near ξ *Geminorum* with radiant at $99° + 13°$. The latter is a well-known companion radiant to the *Orionids*, and it seems to have been unusually active in 1900, yielding very swift streak-leaving meteors. The true *Orionids* appeared to be less numerous than usual, but not many observations were obtained between October 18 and 22. October 21 was a beautifully clear frosty night, and several very fine meteors were recorded at various places. The most brilliant of these were not *Orionids*, as they travelled slowly from radiants in the S. and S.W. quarters of the sky.

November Meteors.—The non-arrival of the *Leonids* formed a marked and disappointing feature of the observations made at the middle of November. They were sedulously looked for at all the chief observatories, and large numbers of amateur astronomers and private persons made efforts to witness the display should it appear. But the same story of meagre results comes from all parts of the globe. There were a few *Leonids*, it is true, with their characteristic streaks and rapid flights, but a brilliant exhibition such as that of 1866 was entirely wanting. In fact the shower, such as it was, scarcely excelled several of the contemporary streams of the epoch. The true explanation doubtless lies in the fact stated by Dr. Downing, that the dense body of meteors has been perturbed by the major planets in sufficient degree to enable it to escape *rencontre* with the Earth. However much we may deplore the conditions which produced this result, we shall hope for a revival of the shower and will continue to watch

for any stray *Leonids* that may appear on or about November 15 in the few ensuing years. In 1900 they were most numerous on the morning of November 15, when 2 or 3 per hour were counted by single observers. But this rate is far below that observed in 1879 and 1888 when the parent comet was not very far distant from perihelion. From the reports of various observers it is certain that during the last few years the *Leonid* shower, instead of showing increasing numbers, has perceptibly declined until it has become scarcely noticeable. In 1900 one of the chief mid-November showers was the *Taurids*, which supplied some very brilliant slow-moving meteors.

The *Andromedids* were looked for by Prof. Herschel, Mr. A. King, and others during the last week of November, but very few of the meteors were seen. As the shower recurred actively in 1899, a bright display was not expected.

December Meteors.—Mr. T. H. Astbury, at Wallingford, Berks, observing on December 13, 8^h 10^m to 9^h, saw 15 *Geminids* and a few other meteors. At a later hour the shower had become less active. On other nights of the epoch the sky was overcast at Wallingford. Mr. C. L. Brook, at Meltham, near Huddersfield, saw a fair number of *Geminids* both on December 11 and 12. Prof. Herschel, at Slough, watched on December 13 between $11\frac{3}{4}^h$ and $13\frac{1}{4}^h$ and saw about 20 meteors, including about 6 *Geminids*. The various reports show that the shower returned in fair strength and that it was observed to the best advantage on the very clear night of December 13.

The following is a list of real paths of bright meteors observed in England during the past year :—

Date. 1900.		G.M.T. h	m	Brightness.	Height at First. miles.	Height at End. miles	Length of Path. miles	Velocity per Sec. miles	Radiant Point. ° °	Observers.
Jan.	2	11	58½	> 1	57	40	44	22	228 + 53	2
	9	2	55	☽	59	23	174	...	280 − 12	10
May	3	13	58	2	54	49	155	28	337 ± 0	2
	5	8	20	F	64	43	112	20	245 + 5	15
June	10	9	10	F	65	28	55	32	336 + 73	9
July	15	10	13	2 × ♀	51	21	78	16	297 − 11	3
	17	8	47	F	58	15	175	slow	249 − 20	17
	18	11	33½	♃	52	50	45	11	214 − 10	3
	19	11	49	> 1 − ♃	81	54	43	35	17 + 50	2
	24	10	49	3 × ♀	68	27	103	19	280 − 15	5
	30	10	45	F	95	50	92	swift	30 + 52	5
Aug.	19	10	36	3 × ♀	56	29	62	slow	346 ± 1	3
Sept.	2	6	54	F	85	20	84	slow	334 + 57	37
	16	8	44	2 × ♀	50	32	86	slow	324 − 25	4
Oct.	21	8	35¼	= ☽	68	20	66	11	300 + 22	300
	,,	11	58	♀	63	48	37	25	350 − 4	2
	27	11	42	3 × ♀	76	67	34	42	136 + 34	2
Nov.	27	11	10	> ♀	57	17	40	...	47 + 45	3
Dec.	13	10	18½	> 1	59	44	24	...	109 + 24	2

Principal Meteoric Showers observed in 1900.

Date.	Radiant.	No. of Meteors.	Observer.	
Jan. 2	$229^\circ + 52^\circ$	29	A. S. H.	*Quadrantids*
„	230 + 54	13	W. E. B.	„
April 16–21	218 − 31	13	A. S. H. & others.	
„	255 + 27 }	12	„	
„	255 + 37 }			
„	233 + 63	11	„	
„	275 + 35	23	„	*Lyrids*
July 18–30	316 + 48	9	W. F. D.	
24–30	338 − 10	24	„	*Aquarids*
30	31 + 54	10	„	*Perseids*
July–Aug.	335 + 72	12	„	
Aug. 18–26	346 + 1	12	„	
Aug. 22–26	333 + 28	11	„	
Aug. 24–Sept. 2 ... ... }				
Sept. 29–30 ... ... }	47 + 43	14	„	
Oct. 23–27 ... ... }				
Aug.–Sept.	72 + 65	11	„	
Aug. 12	48 + 58	12	A. K.	*Perseids*
Sept. 1–20	334 + 57	12	W. F. D.	
Oct. 23–27	99 + 13	13	„	
Oct.–Nov.	57 + 9	11	A. S. H.	
„	57 + 18	11	„	
„	44 + 12	10	„	
Oct. 23–27	43 + 12	8	W. F. D.	
Nov. 14–15	150 + 22		W. E. B.	*Leonids*
Nov. 15	151 + 23	6	T. H. A.	„

A. S. H., Prof. A. S. Herschel; W. E. B., W. E. Besley; A. K., A. King; W. F. D., W. F. Denning; T. H. A., T. H. Astbury.

Stationary Radiation of Meteors.—This interesting feature has recently been investigated and discussed by Professors H. H. Turner and A. S. Herschel, Dr. Bredikhine, M. O. Callandreau, and others. Professor Turner has suggested (*Monthly Notices*, 1899 January and 1900 April) that meteors in passing near the Earth are perturbed in such a manner that after a very long interval of time its cumulative effect on an originally compact group is to distribute it along a considerable section of, if not completely round, the Earth's orbit. The character of the disturbance is such that the apparent radiant of the meteors remains unaltered, while the duration of the shower is much protracted. Professor

Herschel, while admitting the ingenious and simple nature of Professor Turner's theory, has offered another possible explanation. He assumes the existence of a ring of small planetary bodies round the Earth, into which meteors ejected from stars (distant suns), and having enormous velocities (in accordance with the late Mr. R. A. Proctor's views), were dashed. These violent incursions must expel many of the constituents of the ring, and it is this *débris* which in later times is supposed to have supplied stationary radiants. The fragments forming the *débris* would set off in new orbits round the Sun, and returning to the Earth must present one and the same relative radiants imparted to them by the volleying from celestial spaces. Dr. Bredikhine, in the *Bulletin de l'Académie Impériale des Sciences de St-Pétersbourg*, has combated Professor Turner's view, and feels disposed to explain stationary radiation on the idea that it is an apparent effect due to the sequence and commingling of different streams exhibiting many varieties of orbit. Meteoric systems are so numerous that several showers must often succeed each other from similar if not identical directions, though the orbital elements present little resemblance. But M. Bredikhine in a further communication practically admits that stationary radiants within moderate limits (five or six weeks) of duration may be the outcome of perturbation by the larger planets upon the meteoric particles. M. O. Callandreau has also approached this subject, and concludes that if the condition (derived from the criterion of Tisserand, in *Comptes Rendus* for 1891) is fulfilled, there may ensue repetitions of active showers presenting all the appearance of stationary radiants. But in the case of radiants enduring for several months, it must be possible to comprehend in the same family of meteors motions direct and retrograde, and with perihelion distances differing greatly from each other.

Supposed Ancient Showers of Andromedids.—Professor D. Eginitis, Director of the Observatory at Athens, alludes in his report for 1899 to some ancient meteoric showers. A display lasting all night was described by the patriarch Nicephorus, and its historical connections indicate the year as 752. This may have been an ancient storm of *Andromedids*, as three returns of Biela's Comet are equal to twenty years, and the meteors were seen in 1852, 1872, and 1892. Theophanes records that in the year of the famous revolt of Nika (532) a great fall of stars came from the evening till the dawn. M. Eginitis considers this another return of the *Andromedids*, as it corresponds with the 20-year period. There was a meteoric shower in the autumn of 558, and a large comet in 518. These may possibly comform with the *Andromedid* displays of 1798 and 1838. The *Lyrids* of April are probably represented by a shower recorded in 763 by Theophanes, and in 1122 by Domno Alberico.

*Velocity of Meteors determined by Photography.**—The instru-

* From a paper by Dr. W. L. Elkin read before the Astronomical and Astrophysical Society of America at its second meeting, 1900.

ments in use at the Yale Observatory, U.S.A., for the photographic observation of meteors have been supplied with an arrangement for the determination of their velocity. The idea seems to have been first suggested by J. Homer Lane in 1860. An attempt was made in 1885, on the occasion of the *Andromedids* by Zenker at Berlin, and the suggestion was lately revived by Professor Fitzgerald. The Yale apparatus consists of a bicycle-wheel rotating in front of the cameras, and carrying a number of opaque screens. There are at present twelve of these screens, and the rotation is effected at the rate of thirty to fifty turns a minute, by means of a small motor worked by three or four bichromate cells. It will be advisable to increase the number of occultations. At each revolution a record is made at the chronograph, so that the wheel's velocity at any instant is always known. The length of the interruption of a meteor trail and the resulting velocity are easily derived from the plates if the meteor is also recorded on a plate at a second station at Hamden, distant about 3280 yards. With the exception of one of the *Andromedids* much smaller velocities than those derived on the assumption of a cometary velocity were found. The observed velocities lead to orbits of a very improbable character, having periods from 1·25 to 1·80 year, so that it would seem an almost certain conclusion that the atmospheric retardation has amounted to from five to nine miles. The following are the radiants and velocities determined from the observations :—

Date. 1899.	G.M.T. h m s	Apparent Radiant. α °	δ °	Observed Heights. Miles.	Miles.	Observed Velocity. Miles.	Computed Velocity. Miles.	Meteor.
July 31	17 4 30	28·55	+57·31	55	47	31·3	36·2	Perseid
Aug. 7	14 25 25	288·12	− 6·20	31	28	7·6	16·9	
Aug. 8	16 32 47	43·55	+56·33	63	59	31·3	37·5	Perseid
Nov. 24	16 31 25	27·43	+40·33	58	56	12·5	12·2	Andromedid
Dec. 12	21 43 0	113·44	+33·36	56	54	22·7	30·8	Geminid

Solar Activity in 1900.

The diminution of solar activity has steadily continued during the past year, and if the minimum has not been already reached, it is very near. The Stonyhurst drawings, supplemented by eye-observations made by Mr. Hadden of Alta, Iowa, U.S.A., and Professor Moye of Montpellier, show that the sun was spotless on 156 of the 312 days of observation, or on 50 per cent. The percentage numbers of spotless days from the Greenwich records for the two years preceding were 13·2 and 33·7 respectively. The yearly mean of the visible disc-area of the spots from the Stonyhurst drawings is 0·55, a diminution of 28·6 per cent. as compared with the mean 0·77 for the year 1899. The greatest visible actual area shown on the Greenwich photographs on any single day by any individual group was

attained on June 30 by the group which reached the western limb on July 1. This was due to a sudden enlargement of a group which had been quite small during the major part of its period of visibility. The greatest average area for any group was attained by the moderately large group which crossed the disc during October 17–28, and re-appeared again November 13–23. Since that date, until the end of 1901 January, the Sun has been spotless, with the exception of three or four days on which minute dots were seen on the surface. There has also been a remarkable absence of bright faculæ during several considerable periods, and the observations of M. Guillaume made at Lyon show a diminution in the mean area of the faculæ for the first nine months of 1900 of 34 per cent. as compared with the same period of the previous year. The same observer reports the appearance of a small spot in a very high latitude—48° N.—on September 15, but it must have been very faint or very short-lived, as the Greenwich photographs do not confirm it. But on September 2 and 3 a group consisting of two small spots in dense bright faculæ, and nearing the preceding limb, was drawn at Stonyhurst as in longitude 105° and south longitude 25°, and was also observed at Lyon and Greenwich. The same group is probably identical with that observed on August 29 and 30 by Mr. Hadden in high south latitude, although the Sun's disc was absolutely clear on August 31. This group is in all likelihood the harbinger of the new cycle, and its appearance, taken with the fact of the present absolute quiet of the Sun's surface, would point to the presence of the minimum. The chief periods of solar-spot quiet during the year have been January 2–10, February 16–March 1, March 12–24, May 8–13, June 4–13, July 5–15, July 26–August 6, August 17–29, September 13–October 6, October 29–November 11, November 27–1901 January 31. Not only have the spot-groups seen during the past year been small in area, but, with the exception of three or four groups which appeared a second time, they have been very evanescent in character. In type they have been mostly groups of small spots, and there was no example of the formation of a round regular spot with a dark umbra. Even in such groups as appeared of the two-spot type the umbræ of the principal spots were soon disrupted by the formation of bridges.

A. L. C. and E. W. M.

Solar Prominences in 1900.

A very slight reduction in the mean numbers observed is shown for the past year, although the average size of the prominences has actually increased a little.

Compared with 1899 the mean daily numbers are :—

	1899.	1900.
North hemisphere	3·27	3·17
South ,, ...	3·73	3·61
Total	7·00	6·78

The distribution in latitude appears to have followed very closely that observed for several years past, and the limit in high latitudes, beyond which prominences are practically absent, has been as well marked as in every year since 1894, when the high latitude zones of activity closed in over both poles simultaneously and large prominences were frequent in the polar regions.

The position of the limit in both hemispheres and for the last three years has been approximately :—

	North Hemisphere.	South Hemisphere.
1898	$+56^\circ$	-53°
1899	+54	−53
1900	+60	−55

It is of interest to note that this limit of prominence formation towards the poles appears to correspond with the north and south edges of the great coronal streamers, as observed in recent eclipses. The mean position of the edges of the east and west streamers in 1898 and 1900 are a few degrees nearer the poles than the prominence limits; but conforming to the latter, as indicated in the above table, the streamers approach nearer to the pole in the northern hemisphere than in the southern.

Metallic prominences have been very infrequent during 1900, three only being observed. These were recorded as follows :—

Date.			Solar Latitude.	
1900 September	21	... ...	-2°	W. limb.
„ October	2	... ...	-18° to 25°	W. „
„ „	16	... ...	-15°	E. „

No large prominences of the eruptive class have been observed.

J. E.

Total Solar Eclipses.

1900 *May* 28.

The track of this eclipse, which lay over the United States, through Portugal and Spain to Algiers, offered a number of accessible points of observation for both American and European astronomers, and, as the weather conditions throughout the whole length of the line were entirely favourable, a large number of observations and photographs were secured.

The British official parties were distributed as follows :—

(1) At Ovar, on the coast of Portugal, Mr. Christie took photographs of the corona with the Thompson photo-heliograph, similar to those taken in India in 1898, while Mr. Davidson under his direction secured photographs on a small scale showing

the extension of the corona; and Mr. Dyson secured a series of slit spectroscope photographs showing the spectrum of the Sun's limb and of the corona.

(2) At Santa Pola, in Spain, Sir J. N. Lockyer and party, assisted by the officers and men of H.M.S. "Theseus," carried out an extensive series of observations, similar in scope to those which the same observers carried out at Viziadrug in 1898. The prismatic camera work was extended by using a lens of longer focus and consequently obtaining a greater linear extension in the resulting photographs. The series obtained gives a complete record of the spectrum of the chromosphere at various depths, and is apparently quite similar in character to that obtained before.

At this same station Dr. Copeland took photographs with the 40-foot telescope of 4-inch aperture, and with a small Iceland spar and quartz prismatic camera.

(3) At Algiers Professor Turner used the photo-heliograph objective with the Dallmeyer secondary magnifier to obtain corona photographs on a scale of $1\frac{3}{8}$ inch to the Sun's diameter. The two "Abney" lenses were not used separately on this occasion, as it had been thought preferable to recombine them into a doublet. The series of photographs of the corona, dating from 1882, secured by these lenses has therefore been broken. It was considered that there was no advantage to be gained by its continuance, as the photographs resulting from the use of the two lenses with secondary magnifiers are in every way superior. Professor Turner also took photographs with a polariscopic camera, the results of which are interesting, and show plainly the polarisation of the corona, though their full meaning cannot be discussed until the quantitative measurements are made. Mr. Newall, who was also at Algiers, planned and successfully executed an important series of observations, embracing slit spectroscope photographs of the Sun's limb and corona with a four-prism spectroscope, spectroscopic photographs of the corona with a large objective grating, and photographs with a polariscopic camera, consisting of Savart plates in front of a Nicol's prism. The resulting photographs with the latter instrument show strong Savart bands over the corona, and as a very complete series of observations on the general polarisation of the sky were made at the same time, the full discussion of these observations is likely to lead to important conclusions.

(4) At Mazapan, in Algeria, Mr. Evershed used three prismatic cameras, one of 2-inch aperture with two crown glass prisms, one of 9-inch aperture with two flint prisms, and one of about 1-inch aperture with two double quartz prisms. The station was specially selected in order that it might be as near as possible to the edge of the band of totality and photographs of the chromosphere spectrum thus obtained in high solar latitudes. Though, owing to an error in the *Nautical Almanac* value for the lunar diameter, the actual station was found to be

just outside the limit of totality, the series of photographs are nevertheless of high interest, and establish the fact that the spectrum of the Sun's limb is the same in polar regions as in low latitudes. From these photographs, as well as from those obtained by other observers, it seems certain that the spectrum of the Sun's limb is as constant in character as the dark line spectrum.

Mr. Wesley, who by the courtesy of M. Trépied, Director of the Algiers Observatory, had placed at his disposal the equatorial coudé of 0·3-metre aperture, observed the corona directly, principally with the view of determining whether it showed finer structure than is visible in the photographs, an observation for which his large experience and study of corona photographs rendered him peculiarly competent. His conclusions were definite and negative, *i.e.* that all the detail which can be distinguished by the eye in a telescope is visible on good photographs taken on a sufficiently large scale.

In addition to the official observers parties from Dublin and Edinburgh and a large number of members of the British Astronomical Association proceeded to stations on the line of totality and made successful observations. Among these may be mentioned Dr. Rambaut, Mr. W. E. Wilson, Dr. Downing, Mr. and Mrs. Maunder, Mr. Crommelin, Mr. Franklin-Adams, and the Rev. J. M. Bacon.

Some French and German astronomers also observed, but no complete reports of their results are yet to hand. The American astronomers made very complete arrangements for observations in that portion of the shadow track that crossed their continent. Space does not permit of more than a brief mention of the more important work.

The U.S. Naval Observatory equipped two stations where, in addition to the usual corona photography, an extensive series of prismatic cameras and objective gratings were employed in the skilful hands of Doctors Ames, Crew, and Humphreys, Mr. Jewell, and Dr. Huff.

From the Smithsonian Observatory an expedition, under the direction of Professor Langley, undertook a programme of work, the most important items of which were photographs of the corona with a telescope of 12-inch aperture and 135 foot focus, used with a cœlostat, and bolometer observations of the inner corona.

The series of photographs obtained with the large instrument are particularly fine, and show a great wealth of detail in the inner corona.

The bolometer results appear to Professor Langley to show that the corona neither reflects much light from the Sun nor emits much heat of its own, and therefore seems rather to be giving light in a manner not associated with a high temperature.

The Yerkes Observatory party successfully employed a number of prismatic cameras, the results of which have been discussed by Professor Frost, who arrives at the conclusion that

the existence of a reversing layer at the base of the chromosphere is fully confirmed. Professor Barnard used a telescope of 61·5 foot focus and 6-inch aperture for photographing the corona, and obtained views showing the inner corona and prominences with great perfection.

Professor Hale attempted a determination of the heat radiation with the bolometer, but, owing to an unfortunate accident, no results were secured.

The Harvard Observatory party, under the leadership of Mr. W. H. Pickering, in addition to an extensive programme of photographic and spectroscopic work, undertook an elaborate search for an intra-Mercurial planet with a battery of nineteen cameras, which, however, proved abortive.

In addition to the above there were also parties from Princeton Observatory, Brown University, Georgetown College, and some others, but no details are yet to hand showing that results of any special importance were secured.

Professor D. P. Todd was stationed at Tripoli, at the eastern end of the line of totality, and used for the first time his automatic battery of instruments.

Mr. Burckhalter successfully employed his rotating sector apparatus for graduating the exposures in the corona photographs, and obtained some views of great beauty.

To summarise the results we may say that this eclipse is not remarkable for any striking advance. The spectroscopic records are not essentially different from, nor are they superior to, those obtained in India in 1898, and, while the detailed examination of the plates may bring new facts to light, it would at present appear that they practically only confirm the Indian results.

The polariscopic work is of undoubted importance, and when fully examined may throw light on the question of the physical condition of the corona.

The bolometric results are interesting, and if further observations of this character should confirm the idea of the absence of heat or infra-red rays the case for the electrical origin of the coronal light will be a strong one.

The corona was of the same type as those of 1878 and 1889.

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The long duration of totality makes this eclipse an important one, and it is to be regretted that the great distance of the shadow track from England renders it impossible for many observers to spare the time for the necessary journey. As far as is known at present, Mr. Maunder will proceed to Mauritius, and Messrs. Dyson and Newall to Sumatra. The latter will again attempt the spectroscopic determination of the rotation of the corona, which failed in India owing to insufficient exposure of the plate.

As on this occasion an exposure of about three times the former amount can be given, it is to be hoped that a successful result will be obtained.

E. H. H.

Double Stars.

The following summary of references is arranged under two heads, "Observation" and "Calculation," as in former reports, and abbreviated titles have been used as follows :—

M. N.: Monthly Notices R.A.S.
A. N.: Astronomische Nachrichten.
A. J.: Astronomical Journal.
Ast. Soc. Pac.: Astronomical Society of the Pacific.

Observation.—Attention may first be called to measures of a few special stars :—

70 *Ophiuchi*	Schur, *A. N.* 3621, Bd. 151, Göttingen heliometer, 1899.
β 883 ...	E. E. Barnard, *A. J.* 477, vol. xx. p. 170, measures in 1898 and 1899.
	R. G. Aitken, *A. N.* 3638-9, Bd. 152, in 1899.
	T. Lewis, *M. N.* 1900 April, vol. lx. p. 492, in 1899.
Sirius ...	E. E. Barnard, *A. J.* 477, vol. xx. p. 167, in 1899·8.
	T. J. See, *A. N.* 3654, Bd. 153, in 1900·3.
	R. G. Aitken, *A. N.* 3638, Bd. 152, in 1899.
Procyon ...	E. E. Barnard, *A. J.* 482, vol. xxi. p. 16, in 1898–9–1900.
	T. J. See, *A. N.* 3654, Bd. 153, in 1900·3.
	R. G. Aitken, *A. N.* 3638–9, Bd. 152.
	T. Lewis, *M. N.* 1900 April, vol. lx.

The following papers deal with observations of Double Stars :—

New Double Stars—

Royal Observatory, Greenwich. *M. N.* 1900 June, vol. lx. p. 595. "*Capella* as a double star."

Hussey and Aitken. *Ast. Soc. Pac.* No. 75, vol. xii. pp. 201, 202. "*Capella* as a visual double."

E. E. Barnard. *A. N.* 3621, Bd. 151, New Triple B. D. $+34^\circ \cdot 732$.

W. J. Hussey. *A. J.* 480, vol. xx. 100 new doubles in zone -10° to -13° Dec., 40 pairs under $1''$.

W. J. Hussey. *A. J.* 485, vol. xxi., 100 new doubles, 25 under $0''\cdot 5$.

R. G. Aitken. *A. N.* 3635, Bd. 152, 47 new pairs in zone -2° to -10° Dec.; 16 under $1''$.

R. G. Aitken. *Ast. Soc. Pac.* No. 74, vol. xii. p. 127, 5 new pairs.

R. G. Aitken. *A. N.* 3668, Bd. 153, 62 new pairs, 12 under 0″·5.

C. D. Perrine. *Ast. Soc. Pac.* No. 74, vol. xii. p. 129, 2 new pairs.

In the course of the year 1900 the following papers have also appeared :—

Doberck. *A. N.* 3680–1. Measures of double stars made with the 14-inch refractor at Copenhagen in the year 1900.

Glasenapp. "Mesures micrométriques d'étoiles doubles faites à Domkino et à St-Pétersbourg, 1899." Northern pairs 70 under 5″·0, 128 over 5″·0.

Knorre, A. N. 3632, Bd. 152. "Beobachtungen von Doppelsternen, Berlin." Double-image micrometer on 9·6 inch refractor, 26 Σ pairs about 3″.

Boothroyd and Cogshall. *A. J.* 478, vol. xx. p. 173. Double-star measures made with the Lowell 24-inch refractor in 1898. All of these relate to Burnham stars, 145 pairs.

Cogshall. *A. J.* 486, vol. xxi. p. 41. Observation of Dr. See's stars between 18^h and 24^h. A fine set of measures. He finds changes in λ 348, 370, 388, 389, 435, 441, 469, 474.

Aitken. *A. N.* 3638–9, Bd. 152. Measures of 204 pairs, made with the 36-inch refractor of the Lick Observatory. Many are difficult Burnham stars.

Stimson Brown. *A. N.* 3645–6, Bd. 152. Measures of 250 pairs made in 1897–8–9 with 26-inch Washington refractor; 37 under 0″·5.

J. Comas Solá. *A. N.* 3679, Bd. 154. Measures of 60 selected pairs made with 6-inch refractor by Grubb. 4th series.

Royal Observatory, Greenwich. *M. N.*, 1900 April, vol. lx. 494. "Results of Micrometric measures of double stars made with the 28-inch refractor in the year 1899."

Royal Observatory, Greenwich. *M. N.* 1900 April, vol. lx., p. 516. Measures of double stars from photographs taken with the 26-inch Thompson refractor.

E. E. Barnard. *A. J.* 488, vol. xxi. p. 64. "Measures of *Krueger* 60 and β 1291." Note pointing out motion in β 1291.

R. G. Aitken. *Ast. Soc. Pac.* No. 76. Measures of κ *Pegasi* in 1900.

Calculation.—The following papers dealing with calculation and general literature have appeared in the course of the year :—

95 *Ceti* ...	T. J. See, *A. N.* 3629, Bd. 152; orbit, period 150 years.
τ *Cygni* ...	T. J. See, *A. N.* 3629, Bd. 152; orbit, period 57·25 years.
τ *Cygni* ...	R. G. Aitken, *Ast. Soc. Pac.* No. 74, vol. xii. p. 103; orbit, period 45·1 years.
β 883 ...	T. Lewis, *M. N.* 1900 Apr., vol. lx. p. 492; orbit, period 15·8 years.

Σ 367 ...	Dr. Glasenapp, *A. N.* 3669, Bd. 153; orbit, period 224 years.
ζ *Herculis*	T. Lewis, *M. N.* 1900 December, vol. lxi. p. 74; orbit, period 32 to 35 years.
OΣ 341 ...	W. Hussey, *Ast. Soc. Pac.* No. 72, vol. xii. p. 38; note on, as a rapid binary.
OΣ 165 ...	W. Hussey, *Ast. Soc. Pac.* No. 75; motion due to proper motion.
β 107 ...	Dr. Kreutz, *A. N.* 3652, Bd. 153; identification of, note on motion.
Capella ...	W. H. M. Christie, *M. N.* 1900 December, vol. lxi. p. 70; orbit, 104 days.
δ *Equulei*	W. Hussey, *Ast. Soc. Pac.* No. 76, orbit, period 5·8 years.
99 *Herculis*	R. G. Aitken, *Ast. Soc. Pac.* No. 76, orbit, period 63 years.

W. Hussey. *Ast. Soc. Pac.* No. 74. "Notes on the progress of double-star astronomy."

H. C. Plummer. "An application of projective geometry to binary star orbits." *M. N.* 1900 April, vol. lx. p. 485.

Beyond those works already tabulated, Professor Burnham's *General Catalogue* calls for special notice.

The general catalogue of stars discovered by Professor Burnham forms vol. i. of the Yerkes publications. It is modelled on the same lines as those adopted in the publications of the Lick Observatory. The stars are arranged in order of Right Ascension, with all the measures of each pair in chronological order; notes are added where necessary, also diagrams and orbits and complete references to the original sources. Hence those stars needing observation can be at once noted. In all there are 1290 pairs, of which 723 have separations less than 2″, and about 200 may already be classed as binary, while five have completed at least one revolution under Professor Burnham's own observation, viz.:—

β 989,	κ Pegasi,	period	11·4	years
β 883		„	15·8	„
β 101,	9 Argûs,	„	23·3	„
β 733,	85 Pegasi,	„	25·7	„
β 151,	β Delphini,	„	26·7	„

Both by his discoveries and researches Professor Burnham has established for himself a remarkable position as leader in this branch of astronomy. The introduction to the volume is of great value; and even astronomers not directly interested in double star work will find in it ample material for study. His experience of telescopes must be unique. A list of those used by him is here appended, with the number of double stars discovered with each.

6-inch	Private Observatory	451
18½ "	Dearborn "	413
36 "	Lick "	198
15½ "	Washburn "	87
12 "	Lick "	56
9·4 "	Dartmouth "	24
26 "	Naval Observatory, Washington	14
40 "	Yerkes Observatory	8
16 "	Warner Observatory	2
		1253

T. L.

Variable Stars.

The subject of variable stars is coming into increased prominence, as in it are included problems of orbital and physical (or chemical) change, which are dealt with also by the spectroscope; and the correspondence of visual or photometric observations of light changes with spectral changes adds an enormous reality, so to say, to numberless phenomena in the stellar universe. Up to the past few years variable stars were looked upon as more or less outside the pale of ordinary observatory routine, but there is now great activity in this department of astronomy, especially in America, where the discovery of many variable stars in star-clusters by Professor S. I. Bailey is perhaps one of the most notable advances in late years, opening up deep questions in cosmical physics.

Out of 19,050 stars examined by Professor Bailey in certain star-clusters, 509 are found to be variable. Thus there are in the cluster *Messier* 3 132 variables, in ω *Centauri* 125, in *Messier* 5 85, *Messier* 15 51, and so on in diminishing numbers in other clusters. Of the 106 variables in ω *Centauri* whose periods have been determined, 98 have periods less than twenty-four hours. The longest period is 475 days, the shortest $6^h\ 11^m$. The largest range in variation is about five magnitudes. Professor Pickering points to the remarkable regularity in the period of these stars as worthy of attention. Up to the present variables have not been discovered in any except dense globular clusters, of which *Messier* 3, *Messier* 5, and the great cluster in *Hercules* may be taken as examples.

In *Messier* 5 all the variables have nearly the same period, about half-a-day, and nearly same range of magnitude, 14^m to 15^m. Dr. Johnstone Stoney considers these stars were probably nearly alike in physical condition, brightness, star-spot period, and period of internal dynamical vibration. If so, the resemblance would continue during their subsequent history, and he suggests in consequence of shrinkage the star-spot period and the

period of internal dynamical vibration have become nearly equal.

Professor Pickering continues the work of observation of variables for which the Harvard College Observatory is so famous, and we learn that 24,000 photometric comparisons have been made for the year ending September 30 last. Amongst a vast quantity of other work, the observations of 17 circumpolar variables of long period made by Argelander's method from 1890 to 1899 are in print and will shortly be distributed; 30,000 observations of 128 variables in ω *Centauri* are nearly ready for the printer; and a bibliography of variable stars is in hand, containing 15,000 entries.

With the meridian photometer of this Observatory, the observations of stars south of dec. $-30°$ of $7^{m}\cdot0$, and brighter, were completed early in December at Arequipa, and the total number of settings, including those made with the first meridian photometer, reaches the enormous total of 999,864—*i.e.* nearly a million observations.

During the examination of photographic plates at the Harvard Observatory, a new star was discovered in the constellation *Aquila* by Mrs. Fleming, making the 6th Nova found in this investigation. Fifty-six new variable stars discovered on plates have not yet been measured and announced.

Turning nearer home, variables have been discovered by Dr. T. D. Anderson, as follows:—

	R.A. h m s	Dec. ° ′ ″		
1	0 8·5	+46 12	(1855).	
2	5 44·1	+15 45	"	
3	17 55 24·7	+19 29 20	(1900).	A comparatively rapid long period var.
4	17 55·6	+54 51	(1855).	
5	19 33 48·2	+ 9 35·4	(1855).	B.D. + 9° 4205.
6	20 11 32·6	+30 46 1		Slower variation.
7	21 6 15·0	+12 12 26	(1855).	A. G. Leipzig I.
8	21 14 7·5	+13 50 17	(1855).	Var. 9·1 to 12·5. Per ± 205^{d}
9	23 48·4	+52 55		

A variable in the position

15 32 42   −54 54·4   (1875). Suspected by Kapteyn

has been confirmed at the Cape. Variation, 8·7 to 9·3 per $12^{d}\cdot68$.

The variability of Sawyer's *Algol* type variable B.D. + 12° 3557 has been confirmed. Duration of normal light $17^{h}\ 28^{m}$; decrease occupies $1^{h}\ 58^{m}$; increase $1^{h}\ 55^{m}$. Variation, $7^{m}\cdot2$ to $7^{m}\cdot7$.

The period of Mme. Ceraski's 2nd *Algol* type variable has been

determined at Harvard as $6^d\ 0^h\ 8^m{\cdot}8$. This differs so slightly from 6^d that for a long time the minima cannot be observed in certain longitudes. Observations were not obtainable in America before this year. Professor Pickering points out that this and four other stars of the Algol type, viz. *S Cancri*, *U Cephei*, *W Delphini*, and +45° 3062 are especially interesting owing to the large variation in light, amounting to about 2 magnitudes in each case.

Sir Cuthbert Peek continues his observations at Rousdon Observatory. During the year 1899 17 maxima and 22 minima were observed; the total during the progress of this line of research being 245 maxima and 214 minima. The stars observed are mostly circumpolar, so that the light fluctuations are watched continuously through the star's period from maximum to maximum.

Every worker in the variable stars will hail with satisfaction an authoritative work giving a map of the vicinity of each well-known variable and a list of magnitudes of the comparison stars. Such a work is now in course of publication, in the shape of *Atlas Stellarum Variabilium*, by Father Hagen, S.J., of the Georgetown College Observatory, U.S.A.

The first three series of this atlas contain charts for stars between 0° and 115° polar distance, whose minimum brightness is beyond the reach of a 3-inch telescope. Series I., II., and III. have been published. Series IV. and V. will include stars whose range of variation can be followed respectively by a 3-inch telescope, and by the naked eye. The magnitudes of the atlas are computed from steps, and made to agree with the Bonn D.M. They can be connected with the photometric scale as soon as Professor Pickering shall have worked out his scheme of standard magnitudes of faint stars. The beauty and delicacy of the maps already published and the great convenience of having them on loose sheets will render the work indispensable to all workers in this line, and its completion will be looked forward to with very great interest.

It may be noted that the *Revised Harvard Photometry* of Professor Pickering contains the photometric magnitudes of some hundreds of comparison stars for variables.

Vol. xxxiii. of the *Annals of Harvard Observatory* contains the reduction of many thousands of observations of variable stars by Argelander, Schönfeld, and Schmidt.

Father Hagen has drawn attention to the MSS. of the late N. R. Pogson, relating to his proposed *Atlas of Variable Stars* (see *Monthly Notices*, vol. lix., p. 57). These comprise elaborate catalogues of comparison stars for a large number of variables and some charts. It does not seem likely these MSS. (which are deposited in *H. C. Obs.*) will appear in print just now in view of the above-mentioned atlas at present in course of publication; but the quality of Pogson's work seems so

good that no doubt it will be published later, when it can be usefully compared with the *Atlas Stell. Var.* E. E. M.

Stellar Spectroscopy in 1900.

New Star.—Professor E. C. Pickering announced in 1900 July that a new star had been discovered in *Aquila* by Mrs. Fleming in the course of her examination of the Draper Memorial photographs. The Harvard photographs show that it was not visible on 96 plates taken between 1886 August 21 and 1898 November 1. It appears, however, on 1899 April 21 as a star of 7th magnitude, and on 1899 October 27 as a star of 10th magnitude. Its spectrum on 1899 July 3 resembled those of other new stars, and on 1899 October 27 it had the characteristics of the spectrum of a gaseous nebula.

Professor Campbell, of the Lick Observatory, made visual observations of the spectrum on 1900 August 27, and found that it consisted of extremely faint continuous light in the green, and three bright bands in the positions of the three principal nebular lines; the bands were very broad (*Astroph. Jour.* xii. 258).

Chemistry of Stars.—Professor W. N. Hartley calls attention (*Astroph. Jour.* xi. 163) to the fact that the lines 4172, 4033± found in stars such as γ *Cygni*, γ *Orionis*, α *Orionis*, α *Cygni*, &c. coincide closely with lines 4172·214, 4033·112, found in the spectrum of *Gallium*. These lines are found also in the solar spectrum and probably also in the chromosphere.

Classification of Stars.—Sir Norman Lockyer contributes a paper on stars of Secchi's Type IV., under the title "The Piscian Stars" (*Proc. R. S.* lxvi. 126), dealing with suggestions of subdivision of the group of stars, which Dunér has specially studied. Lockyer regards the stars of this class as exhibiting signs of an advanced stage in cooling, and searches for evidence of variation from the average spectrum that would support the view that different individuals in this class may be further on in the process of cooling to extinction than others. Starting from the faint appearance of dark carbon flutings in the solar spectrum, and of solar lines in the "Piscian" stars, he is led to divide Dunér's class into seven species, and to regard the changes observed as indicating a gradual fall in temperature. Lockyer accepts the evidence gathered by McClean and Hale as to the dark lines other than flutings, but hesitates to admit the presence of bright lines which Hale has recorded.

Velocity in the Line of Sight.—A noteworthy result in the work of the past year is that many stars are found to have variable velocity. Professor Vogel calls attention to this in the interesting summary which he has published (*Sitz. ber. Berlin Akad.* 1900, xx. 373), dealing with the progress made in the last decade in the determination of stellar motions in the line of sight. A translation of his paper appears in *Astroph. Jour.* xi. 373.

A list of forty-two stars with variable velocity, many of them being now recognised as binary or multiple systems, is here given :—

Star.	Period.	Discoverer.	Date of Discovery.	Remarks.	References.
α Virginis	$4^d{\cdot}013$	Vogel	1889	Dark companion	*A. N.* 125, 305. *Pots. Obs.* vii. 127.
β Persei	...	"	1889	Variable	*A. N.* 123, 289. *Pots. Obs.* vii.
ζ Ursæ Majoris	...	Pickering	1889	Two bright stars	*Amer. Jour. Sci.* xxxix. 46.
β Aurigæ	...	Miss A. C. Maury	1891	" "	4th Report of Draper Memorial, 1890.
β Lyræ	...	Pickering	1891	Variable	*A. N.* 128, 39.
		Belopolsky	1892	...	" 131, 139.
β Orionis	...	Vogel	1892?	...	*Pots. Obs.* vii. 146.
δ Cephei	$5^d{\cdot}375$	Belopolsky	1894	Variable	*A. N.* 136, 281. " 140, 17.
μ_1 Scorpii	$1^d{\cdot}46$	Bailey	1895	Two bright stars	" 142, 11.
V Puppis	$3^d{\cdot}114$	Pickering	1895	Lacaille, 3105 Cord. G. C. 10534	" 142, 107.
η Aquilæ	$7^d{\cdot}176$	Belopolsky	1895	Variable	*Astroph. Jour.* vi. 393. Wright, *Astroph. Jour.* ix. 59.
α_1 Geminorum	$2^d{\cdot}93$	"	1896	Fainter component of Castor	*Bull. Acad. St. Pet.* iv. 341. *Astroph. Jour.* v. 1. *Mem. Spettr. Ital.* 26. " " 28.
λ Tauri	$3^d{\cdot}91$	"	1897	Variable	*A. N.* 145, 281.
ζ Geminorum	$5^d{\cdot}375$	Belopolsky	1898	...	" 149, 239.
		Campbell	1899	...	*Astroph. Jour.* ix. 86.
β Lupi	...	Mrs. Fleming	1898	...	*Harv. Obs. Circular*, 21. *A. N.* 145, 271.
η Pegasi	$2\frac{1}{4}$ years	Campbell	1898	...	*Astroph. Jour.* viii. 159, 293. Belopolsky, *A. N.* 148, 127.
o Leonis	$14\frac{1}{2}$ days	"	1898	In Miss Maury's list of composite spectra	*Astroph. Jour.* viii. 292, 293.
χ Draconis	$9\frac{1}{3}$ months	"	1898	...	*Astroph. Jour.* viii. 293.
θ Ursæ Majoris	5–7 days	Belopolsky	1899	...	*A. N.* 148, 331. " 151, 39.
ι Pegasi	...	Campbell	1899	...	*Astroph. Jour.* ix. 310. Belopolsky, *A. N.* 154. 210
θ Draconis	...	"	1899	...	*Astroph. Jour.* ix. 311.
α Aurigæ	104 days	Campbell Newall	1899	...	" " x. 177. *Monthly Notices*, R.A.S lx. 418.

Star.	Period.	Discoverer.	Date of Discovery.	Remarks.	References.
ε Libræ	Several months	Campbell	1899	...	*Astroph. Jour.* x. 178.
h Draconis	...	"	1899	...	" " "
λ Andromedæ	19·2 days	"	1899	...	" " "
ε Ursæ Majoris	...	"	1899	...	" " "
ω Draconis	...	"	1899	...	" " "
α Ursæ Minoris	3·95 days	"	1899	...	" " x. 180. Frost, *Astroph. Jour.* x. 184. Belopolsky, *A. N.* 152, 199. Vogel, *Sitzb. Berlin Akad.* xx. 388.
β Capricorni	...	"	1899	In Miss Maury's list of composite spectra	*Astroph. Jour.* x. 241.
υ Sagittarii	...	"	1899	...	" " "
β Herculis	...	"	1900	...	" " xi. 140.
ε Leonis	...	W. S. Adams	1900	...	" " xi. 307. Wright, *Astroph. Jour.* xi. 414.
12 Persei	...	Campbell	1900	...	*Astroph. Jour.* xii. 254.
ξ Ursæ Majoris	...	Wright	1900	Brighter star of telescopic binary	" " "
93 Leonis	...	Campbell	1900	...	" " "
β Scuti	...	Wright	1900	...	" " "
d Boötis	...	"	1900	...	" " "
113 Herculis	...	"	1900	...	" " "
2 Scuti	...	"	1900	...	" " "
η Andromedæ	...	Campbell	1900	...	" " "
κ Pegasi	6 days	"	1900	One component of Burnham's binary. Dark companion	" " xii. 256.
δ Orionis	$1^{d}\cdot 92$	Deslandres	1900	...	*C. R.* cxxx.
α Persei	...	Newall	1900	...	*Monthly Notices*, lxi. 12. Vogel, *Sitz. ber. Berlin Akad.* 1901, p. 51.

Reduction of Observations.—In an interesting note (*A. N.*, Bd. 152, 65) Dr. K. Schwarzschild deals with a new method of determining orbits for spectroscopic binaries. It is an extension and simplification of the method suggested by Lehmann-Filhés (*A. N.*, Bd. 136, 17), avoiding the troublesome operations of mechanical quadrature of the velocity-time curve derived from spectroscopic observations.

U 2

New Instruments.—A new refractor, with an aperture of $31\frac{1}{2}$ inches, has been set up at the Potsdam Observatory. Professor Vogel describes briefly (*Astroph. Jour.* xi. 393) two of the spectrographs which have been constructed for use with this equatorial. The more powerful has three flint prisms each of angle 63° 27′, and transmits a beam of which the diameter is $1\frac{1}{4}$ inch. The single-prism instrument transmits a beam 1·4 inch in diameter, and has one prism of refracting angle 60°.

Dr. Hartmann gives (*Zeitschr. f. Inst. Kunde*, xx., translated *Astroph. Jour.* xi. p. 400, and xii. p. 30) a valuable discussion of various points connected with the construction and adjustment of spectrographs in special reference to instruments to be used in connection with the new Potsdam refractor. He compares efficiency of simple and compound prisms, and concludes that only simple prisms should be used in stellar spectrographs. He deals with various methods of adjustment, and concludes his paper by describing a very ingenious diaphragm for covering the slit of a spectrograph. H. F. N.

The Figure of the Moon.

It was first pointed out by Newton that if the Moon were originally fluid, the tide raised by the Earth should have caused the diameter directed towards us to be longer than one at right angles to it, by an amount which he computed to be 186 feet. Lagrange noticed further, that in consequence of the Moon's rotation there should be a slight polar compression, and hence that the figure of the Moon should approximate to an ellipsoid with its least axis perpendicular to the plane of the equator, and its longest directed towards the Earth. The difference of the axes was so small that there seemed but little chance of its being detected by direct observation ; but that the true figure of the Moon is of this form, or at all events that the distribution of mass is such as to give moments of inertia which would correspond to such a figure, is shown both by the existence of a real physical libration, and also by the coincidence of the descending node of the lunar equator with the ascending node of the orbit.

A computation of the tide raised on the Moon, using data given by Laplace, shows the height to be nearly 130 metres, which is greater than Newton's result, but still very small, the difference between high and low tide being less than $\frac{1}{6000}$ of the Moon's radius.

The amount of the physical libration depends upon the ratios of the moments of inertia about the three principal axes, and when these are known the lengths of the axes of the corresponding homogeneous ellipsoid may be computed. Using the values of these ratios which he found from his discussion of Schlüter's observations, Dr. Franz finds that the ratio of the axes should

be 1·0003 : 1 : 0·9997. It was, however, shown by Laplace (*Méc. Cél.* Bk. V. ch. ii. § 18) that the Moon is not homogeneous, and that its figure is different from that which it would assume if it were wholly fluid, so that these results must be considered as not indicating more than the order of magnitude of the ratios to be determined.

The principal direct contributions to the problem have been those of Hansen (*R.A.S. Memoirs*, vol. xxiv.), who, from discordances between the observed and computed longitudes of the Moon, inferred that its centre of figure was 59 kilometres nearer to us than its centre of gravity, and of Gussew (*Bulletin of St. Petersburg Academy*, 1859 October 14), who from measures made on two of De la Rue's photographs, found an elongation towards the Earth of 5·5 per cent. These measures were undertaken at the suggestion of Hansen, and the result lends support to his theory, but is altogether discordant with the estimates derived from the height of the tide and from the physical libration.

Hansen's conclusions were disputed by Newcomb (*Proc. Am. Ass. for the Advancement of Science*, 1868, and *Am. Journal of Science and Arts*, 1868), who was supported by Delaunay at the sitting of the Paris Academy, 1870 January 10, but were defended by their author (*Ber. der Sächs. Gesel. der Wiss., Math.-Phys. Klasse*, Band 23).

Here the question remained until it was taken up by Dr. Franz, who in vol. xxxviii. of the *Königsberg Observations* publishes an account of a series of very careful measures made on five negatives, all taken at the Lick Observatory near the time of full Moon.

As a preliminary to his inquiry, and in order to determine the constants of his plates, Dr. Franz made extended series of heliometer measures of the distances of eight standard points from Mösting A, the position assumed for which was that derived from his discussion of Schlüter's observations, viz. :—

$$\lambda = -5^\circ\ 10'\!\cdot\!32 \pm 0'\!\cdot\!13, \qquad \beta = -3^\circ\ 11'\!\cdot\!40 \pm 0'\!\cdot\!09.$$

The following resulting places form not the least valuable part of Dr. Franz's work : —

Proclus ...	$\lambda = +46^\circ\ 57'\!\cdot\!27 \pm 0'\!\cdot\!57$	$\beta = +16^\circ\ 4'\!\cdot\!78 \pm 0'\!\cdot\!73$
Macrobius *a*...	$+40\ 21\cdot94 \pm 0\cdot52$	$+19\ 32\cdot69 \pm 0\cdot74$
Sharp A ...	$-42\ 33\cdot24 \pm 1\cdot40$	$+47\ 31\cdot78 \pm 0\cdot76$
Aristarchus...	$-47\ 32\cdot43 \pm 0\cdot86$	$+23\ 42\cdot23 \pm 0\cdot80$
Gassendi *z* ...	$-42\ 52\cdot19 \pm 0\cdot58$	$-16\ 27\cdot43 \pm 0\cdot55$
Byrgius A ...	$-63\ 48\cdot23 \pm 1\cdot32$	$-24\ 33\cdot47 \pm 0\cdot75$
Nicolai A ...	$+23\ 38\cdot92 \pm 0\cdot51$	$-42\ 26\cdot97 \pm 0\cdot63$
Fabricius K...	$+42\ 14\cdot63 \pm 0\cdot76$	$-46\ 4\cdot17 \pm 0\cdot86$

The probable errors are those resulting from the discordances of the individual measures; the places would be systematically affected by whatever real error there may be in the position of Mösting A, but, as Dr. Franz remarks, they are of a much higher order of accuracy than those found by measures from the limb.

These positions were used for determining the scale and orientation of the plates, as well as for testing them for any possible deformation due either to optical distortion or to contraction of the film. It was found that errors due to this cause were less than those of observation, the mean error of setting on a crater being 0·013 mm., or about $0''\cdot19$.

The values of the photographic irradiation for the different plates were found by measuring 7 points on the limb, and comparing the resulting diameter with that computed in accordance with the scale as previously found. The results obtained were $+1''\cdot55$, $+1''\cdot30$, $+0''\cdot73$, $+1''\cdot06$, $-0''\cdot11$. In the last plate it was certainly small, the negative result being attributed to irregularities on the limb.

If two photographs of the Moon, taken under different librations, are compared, the effect due to change of libration will be equivalent to a rotation about an axis at right angles to the plane which passes through the two points on the surface which appear respectively as the centres of the discs, and through the centre of the ellipsoid which most nearly represents the figure of the Moon. When the librations are computed the amount of this rotation is known. If a system of longitude and latitude is constructed for which this plane forms the equator, then the effect of the rotation will be to cause an apparent change in the longitude of any point on the surface, its latitude remaining unaltered. The corresponding linear displacement of the image on the photograph will depend upon the distance of the point on the Moon's surface from the axis of rotation, in such a way that when one of the two is known the other can be determined. This linear displacement will have a maximum in the equator, and it is by measuring its value for points, on or near the equators corresponding to different combinations of his five photographs, that Dr. Franz has endeavoured to determine the elongation of the Moon towards the Earth. Seven combinations gave corresponding rotations varying from 10° to 14°. The other three combinations were not employed as the differences of libration were too small.

The principal cause of error encountered was in the difficulty of setting on the Moon's limb in order to determine the coordinates of the centre of the disc. The result has been to cause points measured in the same combination to appear systematically too near to or too far from the axis of rotation, and for two combinations the elongation comes out negative. The final result is

$$\frac{r_1 - r}{r} = +0\cdot00114 \pm 0\cdot00390$$

where the figure of the Moon is supposed to be a prolate spheroid with its longest axis r_1 directed towards the Earth, r being the length of an axis at right angles to this. From this Dr. Franz concludes that the Moon is sensibly spherical, in agreement with the results derived from the theory of tides and from the physical libration, and in opposition to that obtained by Gussew.

In discussing Gussew's observations Dr. Franz calls attention to the fact that he knew only the days on which his photographs were taken. He applied to De la Rue, but was unable to ascertain the exact times, which therefore he had to estimate from the longitudes of the terminators. If we make the supposition that the photographs were taken on the meridian, the times would differ from those assumed by $2^h\ 31^m$ and by 37^m respectively. In this case Gussew's value of the elongation would be reduced by about one half, and it would be possible to find times such that the resulting elongation should vanish altogether. Very little weight therefore is to be attached to his determination.

Dr. Franz has further applied his measures to the problem of finding the altitudes of different parts of the surface above the mean level. When the same point has been measured three or four times the discordances are such as to show that very little reliance can be placed upon the separate determinations, but the grouping of the positive and negative results shows that the northern hemisphere, and especially the north-east quadrant, containing the Oceanus Procellarum, lies the lowest; whilst the southern hemisphere, and especially the mountainous south-west quadrant, is the highest. He gives a coloured contour map constructed in accordance with his measures. S. A. S.

Solar Parallax from Transit of Venus Observations.

In the *Comptes Rendus* of 1899 December 11 M. Bouquet de la Grye has published the results of his discussion of the visual observations of the ten expeditions sent out by the French Academy of Sciences to observe the transit of *Venus* of 1882, with a promise that the results from the measurement of the photographs taken at the same time is to follow shortly. The chief causes that led to a modification of the previous provisional results published in 1884 were the interpretation of the times of contact by the various observers, the rejection of observations made with a double refraction prism placed before the eyepiece (because this apparently diminished the Sun's diameter, and therefore retarded the time of observed second contact and accelerated that of third contact by some 10^s), an allowance for the fact that the object-glasses were lightly silvered over so as to diminish the risk of cracking the coloured eye-shades, and, lastly, more accurate data for the value of the longitudes of the

different stations. These ten different expeditions all occupied stations either in North or South America, the most northerly and southerly of which were separated by 85° of latitude, while the most eastern and western were hardly 3° of longitude apart. The best determination of the solar parallax was therefore to be derived by Halley's method from observation of second and third contact. Eight observers in the northern hemisphere and nine in the southern made the necessary observations, and of these observers five in the northern and three in the southern hemisphere had object-glasses of eight inches aperture. As a matter of curiosity M. Bouquet de la Grye has determined the solar parallax by Halley's method from observations of first and fourth contact, but the individual results, as might be expected, prove to be not very accordant. For the treatment of the observations by Delisle's method, which requires observations of one contact at two stations as far apart as possible in longitude, the available material are as follows: Observations of second contact, 10 at stations south, 12 at stations north, of the equator; observation of third contact, 12 at stations south, 8 at stations north, of the equator. Finally, M. Bouquet de la Grye gives us the definitive result from the French visual observations the value 8″·80 for the solar parallax. The results of the different methods of treatment are as follows:—

Halley's Method.	Solar Parallax.
2nd and 3rd contacts (all instruments)	8″·8068
„ „ „ (8-inch aperture only)	8·7996
1st and 4th „	8·783
Delisle's Method.	
2nd contact, at stations 10 south, 12 north, of equator	8·772
3rd „ „ 12 „ 8 „ „	8·788

W. G. T.

Researches on Stellar Parallax made with the Cape Heliometer.

In vol. viii. pt. ii. of the *Annals of the Royal Observatory Cape of Good Hope*, Sir David Gill publishes the results of his observations of stellar parallax in the southern hemisphere made since 1887. This may, to some extent, be considered as a continuation and extension of his earlier work in the same field published in the *Memoirs of the R.A S.* vol. xlviii. It is, however, of a still higher order of accuracy, and those who have appreciated the value of the earlier series will find here fresh cause to admire the energy and skill which have gone towards the acquisition of these remarkable results.

The measures were made with the new 7-inch heliometer constructed by Messrs. Repsold, Sir David Gill himself, and Messrs. Finlay, de Sitter, and Lowinger taking part in the observations.

A description of the instrument and mode of using it is given in vol. vii. of the same series of annals. This instrument is so greatly superior to the 4-inch heliometer, with which the former results were obtained that Sir David Gill estimates its efficiency as being six times that of its predecessor.

Needless to say, every precaution which previous experience suggested has here been adopted to avoid systematic error in the measures, and it is an agreeable feature of these results that there appears to be no necessity for the application of systematic corrections such as had to be introduced into some of the earlier investigations. In this connexion it may, perhaps, be permitted to express a regret that the parallax of *α Centauri*, which was especially affected by such errors, has not been subjected to a renewed attack with this more powerful instrument, as was done in the case of *Canopus*, *Sirius*, and *β Centauri*.

Sir David Gill has investigated at some length the effect of the chromatic dispersion of the atmosphere upon his results. It is a little unfortunate, perhaps, that the observations were so arranged that in nearly every case the factors for $\Delta\beta$ (the atmospheric dispersion) run almost parallel with those of the parallax, so that the two cannot be separated; but the measures of *δ Sagittarii*—a remarkably red star—made by Messrs. de Sitter and Lowinger, and those of *β Orionis*, made by Sir David Gill himself, seem to show that in these measures the effect of atmospheric dispersion is probably insignificant.

The resulting stellar parallaxes published in this volume are :—

Star.	Mag.	Parallax.	Prob. Error.
Sirius	−1·8	0″·370	±0″·010
Canopus	−1·0	0·000	±0·010
Rigel	0·35	0·000	±0·010
Achernar	0·5	0·043	±0·015
β Centauri	0·8	0·046	±0·017
α Crucis	1·0	0·050	±0·019
Spica	1·2	−0·019	±0·010
Fomalhaut	1·3	0·130	±0·014
α Scorpii	1·3	0·021	±0·012
β Crucis	1·5	0·000	±0·008
α Gruis	1·9	0·015	±0·007
β Hydri	2·9	0·134	±0·007
τ Ceti	3·6	0·310	±0·012
Lacaille 2957	6·0	0·064	±0·024
P. xiv. 212	A 6·3 B 7·9	0·167	±0·008
Z.C. V. 243	8·5	0·312	±0·016

Tables giving, on different assumptions as to the parallaxes of the comparison stars, the light energy of those stars whose *apparent* parallaxes have been determined compared with the light energy of the Sun, and their velocity at right angles to the line of sight, as well as an appendix containing "Auxiliary Tables to facilitate the Selection of Comparison Stars and the Computation of Factors of Stellar Parallax," complete a volume of the highest value and importance to astronomers. A. A. R.

Star Catalogues.

Greenwich Second Ten-Year Catalogue (1890·0).—It is satisfactory to find that the necessity for taking up various new lines of research has not diminished the activity of our national Observatory in meridian observation. The first Ten-Year Catalogue contained 4059 stars; the second, representing the work of an equal number of years, contains 6892—a notable advance in place of any falling off. And just as the increase in quantity is shown by these figures in the very name of the Catalogue, so the steady advance in accuracy is demonstrated by the diagram which forms the frontispiece. Nothing could be more instructive than the comparative curves for the 1860, 1864, 1872, 1880, and 1890 Catalogues, showing the gradual elimination of errors of a systematic kind in the right ascensions of the clock-stars, effected by the simple but drastic expedient of keeping for fundamental places only those observations which extend over a period of twelve hours at least. Other errors of a systematic kind, both in R.A. and N.P.D., have been fully discussed, though sometimes without reaching any conclusion; and again sometimes reaching a conclusion, but finding the corresponding correction too small to be applied. But a large amount of material is collected in the Introduction for those who may be fortunate enough to find from it the hitherto unsuspected clue to some source of error, or may wish to apply corrections which the Astronomer-Royal prefers to leave unapplied.

The most noteworthy discordance still unexplained is the well-known R—D discordance. It has, among other peculiarities, suddenly disappeared, but this was after the conclusion of the observations forming the Catalogue. In 1893–4 it was hoped that some light had been thrown on the nature of this puzzling phenomenon from the discovery that when the D observation was made before the R, instead of afterwards, the discordance changed sign; but another kind of experiment (taking the R and D observations on separate nights) gives results which it is difficult to reconcile with the former, so that matters are much as they were. Another unexplained discordance is that between the nadir observation and the reflexion observations of stars.

Of systematic errors detected, but not allowed for, the most novel are the diurnal variations in the level, azimuth, and nadir-point. The maxima seem to occur about noon and midnight,

and the minima about 6 A.M. and 6 P.M., though the distinction between maximum and minimum is of course arbitrary. Again, the solar observations indicate an equinox correction of about $+0^{s}\cdot05$, which would make the Catalogue agree better with Newcomb's Fundamental Catalogue; but "no correction has been applied, as the uncertainty of the system of proper motions based on Bradley's equinox, and of the observations of the Sun due to the personality of the observers, leaves the determination of the equinox somewhat arbitrary. The equinox of the Catalogue therefore is that of the 1872 Catalogue carried on by the use of Struve-Peters' precessions and Auwers'-Bradley proper motions."

Of errors detected and applied a conspicuous example is afforded by the new division-errors of the circle, which have removed a long known anomaly near the pole.

Very complete discussions of refraction and colatitude, and of comparisons of the Catalogues with others, are given in the Introduction. The evidence is in favour of the Pulkowa refractions, and of a colatitude $38^{\circ}\ 28'\ 21''\cdot80$, or even $21''\cdot75$, instead of $21''\cdot90$ as before; but this does not, of course, mean a real change in latitude. Similar conclusions were reached by a discussion of the previous Ten-Year Catalogue (1880). There is, however, a conspicuous exception to the general trend of the evidence—the Pulkowa refractions do not suit the Sun observations at all well.

The comparisons with other Catalogues include a very complete set with those of the Catalogues of the *Astronomische Gesellschaft*, which should be of the greatest use in the work of the great Astrographic Catalogue. It is also to be remarked that the agreement with Newcomb's Fundamental Catalogue (when the epoch correction is made, and the Pulkowa refractions are used) is practically perfect.

The Catalogue contains a large number of stars well distributed over the northern hemisphere, and suitable for the elucidation of all sorts of systematic errors. But its main feature is the re-observation of 3645 of Groombridge's 4243 stars (1810); and naturally a valuable series of proper motions can be obtained. The largest of these, to the number of 174, are given, with full details, in the Introduction, and complete a fine piece of work in fundamental astronomy.

Cape Catalogue of 1905 *stars for* 1865·0.—The following significant words may be quoted *verbatim* from the Preface: "The publication of this Catalogue marks an epoch in the history of the Observatory. For the first time in that history the Director can feel that the accumulated labours of his predecessors are available for the use of Astronomers, and that the work being done under his own direction is in a healthy and forward state of reduction and publication."

The last of the arrears are thus wiped off in the present catalogue, which represents the meridian work of the years 1861–1870 under Sir Thomas Maclear. A comparison of the catalogue

with Newcomb's fundamental catalogue shows systematic differences in both co-ordinates depending on the declination, but nothing serious depending on R.A. Sir David Gill gives reasons, however, why the catalogue should not be regarded as a fundamental one. One of the reasons is a curious "apparent change of latitude between 1862 and 1863." The correction to adopted latitude ($-33° 56' 3''.20$) shown by circumpolars in the year 1862 is $-0''.27$; in 1863 is $-0''.67$; and in subsequent years to 1870 is $-0''.90$ with small fluctuations. On this Sir David Gill remarks: "I have been unable to find any satisfactory explanation for the marked apparent change of latitude between 1862 and 1863." Referring to the annual results we find that the only instrumental change mentioned about this time is the insertion on 1862 July 28, of a pair of ZD wires at 14″ apart instead of the single one previously used. Nothing is said about the way in which the pair of wires was used, but it is noteworthy that if the latitude observations of the year 1862 be separated by the date just mentioned, the earlier group gives the correction $-0''.43$, agreeing nearly with the $-0''.27$ for 1861, and the later group the correction $-1''.17$, agreeing with 1863 and subsequent years. The curious change is thus possibly connected with this change of wires.

Catalogue of the Astronomische Gesellschaft.—The second half of the Leipzig work containing zones $+10°$ to $+15°$, referred to in the last report as in the press, has since been published. It contains the places of 9547 stars, nearly all observed twice, and a large number of them oftener. The instrument was a 6-inch transit circle by Pistor and Martins; and the observations were made chiefly by Drs. Engelmann and Bruhns in the years 1868 to 1873. For the declinations the general practice was to read only one microscope. A full account is given in the Introduction to this Catalogue of the work for both this zone and for Leipzig II ($+5°$ to $+10°$), published last year.

A catalogue has also been published by the Lund Observatory of the places of the stars observed in zones $+35°$ to $+40°$. The separate observations of each star are given separately; and the stars are not numbered, so that the exact total is not apparent; but there seem to be about 10,000 stars.

The Leiden Catalogue from $+30°$ to $+35°$ has been printed off with the exception of the Introduction, and may thus be expected shortly. This leaves only the Dorpat zone from $+70°$ to $+75°$ outstanding in the northern half of the *Gesellschaft Catalogue.* It is satisfactory to have the completion of so noble a work within sight. H. H. T.

The Cape Photographic and the Cordoba Durchmusterung.

The third and concluding volume of the *C. P. D.*, consisting of the zones from dec. $-53°$ to the South Pole, and the

third volume of the *C. D.* embracing zones from dec. $-42°$ to $-52°$, have been published during the year. The *Cape Photographic Durchmusterung*, of which a brief account was given in the Council Report for 1897 on the appearance of the first volume, extends from dec. $-19°$ to the South Pole. It contains 454,875 stars, being an average of 32·66 to the square degree, and is considered by Dr. Kapteyn to be complete down to the magnitude 9·5 on the scales of Gould, Schönfeld and Thome in the neighbourhood of the Milky Way, and to reach the corresponding photographic magnitude in the rest of the sky. The limit of magnitude to which this survey reaches is stated in this form because Dr. Kapteyn concludes that the stars in the neighbourhood of the Milky Way are more photographically active than those in the rest of the sky. The right ascensions and declinations of the stars are obtained by using the stars observed by Gould in the *Cordoba Zone Catalogues* as reference stars, and the probable error of the deduced positions is about $\pm 2''\cdot 5$ for the right ascensions and about $\pm 3''\cdot 0$ for the declinations. The polar plate reaching to $5°$ from the South Pole has been measured with greater accuracy, the probable errors being $\pm 0''\cdot 53$ and $\pm 0''\cdot 76$ respectively. The magnitudes are deduced from the measured diameters of the star images by the formula $m = \frac{B}{C+d}$, where the constants B and C for each plate are obtained by comparison with the visual magnitudes given in Gould's *Zone Catalogues*. The number of stars used in obtaining the constants B and C generally lies between 70 and 130, and a large majority of these have the magnitudes 8·5, 9·0, and 9·5 in Gould's Catalogue. An extrapolation is necessary for the stars fainter than $9^{m}\cdot 5$ on Gould's scale.

An important feature of this *Durchmusterung* is the extensive manner in which it has been compared with other catalogues and surveys. For example, lists are given of stars of magnitudes 9·0 and brighter given in catalogues of precision and not shown on the plates. This part of the work is still in hand, and Sir David Gill and Dr. Kapteyn state their intention of publishing (*a*) lists of errors found in previous catalogues; (*b*) a list of large and previously unknown proper motions; (*c*) a list of new variables; (*d*) a more exhaustive investigation on the difference in colour between the stars near the Milky Way and the rest of the sky; and (*e*) a comprehensive discussion of photographic magnitudes.

The *Cordoba Durchmusterung*, of which a brief account was given on the publication of the first two volumes in the Council Report for 1894, is now completed from dec. $-22°$ to $-52°$, and the zone $-52°$ to $-62°$ is stated by Dr. Thome to be well advanced. In the part already published there are 489,662 stars, or an average of 57·5 per square degree, and Dr. Thome considers that it is complete to magnitude 10·0, and very nearly so to 10·2. The number of stars observed is much larger than the

number in the *C.P.D.*, but the positions of the stars are less accurate than in that work, the probable errors of the Right Ascensions ranging from $\pm 0^s\cdot 3$ for the brighter stars to $\pm 0^s\cdot 7$ for the faintest, and being $\pm 6''\cdot 0$ for the declinations. It is of interest to notice that comparison with the *C.P.D.* indicates a personal equation with magnitude of $+0^s\cdot 389$ for $9^m\cdot 4$ with a rate of $+0^s\cdot 037$ for each additional tenth.

The chief interest in a Durchmusterung, such as the *C.D.* or the *C.P.D.*, is not the accuracy of the positions, for which great precision is not attempted, but rather in questions relating to magnitude and distribution of the stars. Dr. Thome gives a long list of stars where the range in the observations of magnitude were so large as to lead him to suspect variability.

Naturally the Durchmusterung provides very ample material for studying the distribution of the stars. Dr. Thome gives counts of the stars for each degree of declination and 4^m of Right Ascension. On comparison with the *C.P.D.*, it appears that three times as many stars are shown by the *C.D.* in the sparse regions of the sky, but that in the richer regions of the Milky Way the *C.P.D.* shows more stars than the *C.D.* In the explanation of this interesting fact Dr. Thome and Dr. Kapteyn are at variance, the former attributing it to observational causes, and the latter to a real variation in the quality of the light of the stars near the Milky Way. Without entering into a discussion of this subject, it may be noted that the mere discovery of the fact is a striking instance of the value of making visual observations concurrently with photographic observations. Comparison of Dr. Thome's results with the *Cape Photographic Durchmusterung*, and in due course with the astrographic photographs, will furnish a very comprehensive comparison of visual and photographic magnitudes, and be of very great importance in all discussions of the distribution of the stars in the Southern Hemisphere.

F. W. D.

A Universal Star Catalogue.

In the Annual Report on progress of work undertaken by the Berlin Academy of Sciences, presented at the meeting of January 24, 1901, Professor Auwers gave an account of a new astronomical undertaking, the object of which is to completely collect and exhaustively discuss all determinations of star places obtained by meridian observations at the various observatories during the period 1750–1900, and to form therefrom one General Catalogue of stars for the equinox 1875. This catalogue will contain the most probable positions, derived with due allowance for weights, for the middle epoch of the observations of each star, and the proper motions wherever the observations are sufficient for their determination.

The results of meridian determinations of star places are at

present scattered over more than three hundred different catalogues which are at the present time and will be for many years worthy of consideration in all work depending on accurate positions of stars or dealing with their proper motions. An immense amount of labour is wasted at present, as each astronomer engaged in such work has to collect for himself and consult (very frequently in vain) these many different sources, to bring up their dates to a common equinox, and then to derive the best possible place for the epoch he requires. And the difficulty of mastering a material already so enormously extended and widely scattered goes on increasing, and in all probability—without taking any account of the results of the new method of photographic observations, to be separately dealt with at some future epoch—increasing with the number of working observatories at an accelerated rate. The danger seems great, therefore, that complete acquaintance with existing star catalogues and the possibility of systematically handling them will before long generally be out of the reach of practical astronomers, with the effect that a limited number of catalogues will be selected for future reference, and the rest, though they contain results which will be of service for a long time to come, will be overlooked, and be practically useless.

To establish order within a department which is rapidly being filled with a nearly chaotic mass—to spare astronomers of the twentieth century unlimited waste of labour in incessant repetition of work which can be done once for all—to ensure to sidereal astronomy the permanent possession of all the riches gained by the combined efforts of observers and computers engaged in meridional work during the 150 years which sever the beginning of the twentieth century from the beginning of meridian work of precision—to transform the combined result of all of that work hitherto done into a ready and powerful means for progress—these are the objects of the Berlin Academy in undertaking a universal star catalogue.

The total number of published star places obtained by meridian observations since 1750 is estimated at about one million—excluding all publications of observatories which contain raw observations, or apparent places only—relating to about one-fourth that number of different stars. Considering the enormous extent of a work dealing with this whole mass, it was at first thought advisable to exclude the great zone catalogues, and to confine the collection and discussion to the large mass of special catalogues. It is mainly these that give rise to embarrassment, by their great number—and by scarceness of copies of many of them—and by the great variety of contents and different degrees of accuracy. On closer examination, however, it was found too difficult to draw a convenient line of separation between the catalogues to be included in the collective work and those to be left for special reference, and besides, any limitation would largely diminish the usefulness of the work and necessarily

leave much to be done afterwards. The only reasonable plan, therefore, from the scientific as well as from the economical point of view, clearly appeared to consist in framing the scheme of the work from the beginning on the broadest lines, and to include in it the complete history of every star observed during the last 150 years.

That the work may be really complete for this period, it now becomes extremely desirable that all those series of meridian observations of stars, which, at the present time, are accessible only under the form of observation journals or in an incomplete state of reduction, should be finally reduced and catalogued, where possible by the observatories to whom they belong. This must be done before the Berlin work shall have accomplished the first two of its steps, viz. (1) the collection and chronological arrangement of all published positions of every observed star, and (2) the bringing up of these positions, by precession, to 1875. It is expected that a pretty considerable number of years will be spent upon these parts of the work, so that there is still the possibility of a good deal of useful complementary work being done in the meantime, and of its results being inserted in the right place; but when this stage of the work is once reached, it will be very difficult to introduce any more additions.

The Academy, after having secured, on the occasion of its bicentenary, celebrated in 1900, a permanent endowment for the work, has appointed Dr. F. Ristenpart as chief of the computing office established for the execution of the work, and has charged him with the execution of all the necessary detail under the general superintendence of an Academical Committee of which Professor Auwers is president.

Dr. Ristenpart, aided by repeated special grants out of academical funds before the Academy formally enrolled the "Geschichte des Fixsternhimmels" on the list of its own undertakings, has been at work since 1898, but on a more limited scale for the greater part of the period. During this period the collection and chronological arrangement of catalogued star places has been accomplished to the epoch 1842, and next the positions from Argelander's northern zones will be filled in on the cards. The total number of positions yielded by the catalogues whose epochs are between 1750 and 1842 is about 240,000; but there is hope that this number will be increased by 20,000 to 25,000 from some existing and probably valuable series of unreduced and unpublished but accessible observations.

[The Council is indebted to Dr. Auwers for this note.]

Professor Kapteyn's proposed Durchmusterung for Parallax.

In 1889 Professor Kapteyn proposed that each plate for the astrographic catalogue should be exposed at three successive epochs of maximum parallactic displacement, being carefully preserved in the intervals of six months, and developed after the

third series of exposures. The plates would then furnish, in addition to the positions of the stars, a first determination of their parallaxes. The proposal was not adopted for the catalogue work. But in 1891 Professor Donner undertook to obtain with the astrographic equatorial at Helsingfors a series of plates for a definitive trial of this method of obtaining parallaxes wholesale.

In 1895 Professor Kapteyn set up a Repsold measuring machine in a room which had been placed at his disposal in the physical laboratory at Groningen, and in the intervals which could be spared from his work on the *Cape Photographic Durchmusterung* he has measured and discussed three plates of a region in the Milky Way about the star B.D. $+35°$ 4013, which includes three of the Wolf-Rayet stars. The preliminary results, in the form of a table of the measured parallaxes of 246 stars, were given in *A. N.*, No. 3475, and a full account of the work has just appeared in the first part of the *Publications of the Astronomical Laboratory at Groningen.*

Each star gives rise to an equation of condition of the form

$$\nu = a + bx + cy + dx^2 + exy + fy^2 + \mathrm{H}\pi \,;$$

where x, y are the rectangular coordinates of the star; ν is a function, independent of the proper motion, of the measured distances between corresponding images; π is the parallax relative to the mean of all the stars on the plate; and the six constants a, b, c, d, e, f, include the effects of changes in orientation and scale value, differential refraction and aberration, and in the inclination of the plate to the optical axis.

The values of the six constants for the plate are obtained by an abbreviated least square solution, the term $\mathrm{H}\pi$ in each equation of condition being treated for the time as if it were an accidental error.

The first important point made by Professor Kapteyn is that appreciable terms of the second order may arise from variation due to flexure of the tube in the inclination of the plate to the optical axis; moreover, the displacement given to the plate to secure a series of exposures is equivalent to an inclination, and the equivalent inclination must be kept much smaller than a minute of arc if parallaxes are to be determined all over a plate 2° square. It is therefore useless to compute separately the second order terms in refraction and aberration. The uncertainty in the determination from the measures of the three additional constants diminishes the weight of a parallax in the most unfavourable case by one-tenth only.

It seemed probable *à priori* that distortion of the film might occur during the six months intervals between the exposures. The parallaxes found were therefore divided into twenty-five groups, and means taken for each group on each plate. The numerical values of the means are distributed consistently with their being purely accidental. Professor Kapteyn concludes

that there is no systematic error depending on position, and that the film is not distorted during keeping. It may be considered that this point requires further examination, since on one plate the means have a distinct tendency to be of opposite signs on opposite halves of the plate.

A search for systematic error depending on magnitude leads to results of the highest importance. Personality in measurement has been completely eliminated by reversal. Yet the ten brightest stars have on one plate a mean parallax of $+0''.092$; on the other plates of $+0''.019$ and $+0''.014$. Professor Kapteyn considers that this abnormal result on one plate is due to defective guiding, which has displaced the centre of gravity of the larger discs. In short exposures intended for accurate measurement, guiding by hand must be dispensed with.

If these anomalous results are rejected, and the others collected into magnitude groups, the means are

Mag. 10·2	$\pi = -0''.009$
9·6	$-\ \ .004$
8·6	$+\ \ .013$

Professor Kapteyn considers that the real difference of parallax for these groups must be much smaller. This opinion is based upon an investigation published in *A. N.* 3487. The mean parallaxes for the groups of fainter stars are there derived by extrapolation, the legitimacy of which is perhaps open to question. The greater part of the difference is attributed to "hour angle error," due to atmospheric dispersion. The plates were taken about hour angles 5^h E. and 3^h W.

To confirm this conclusion Professor Kapteyn examines the residuals in Dr. Wilsing's measures of the distance between the two components of 61 *Cygni* (*Publ. Astrophys. Obs. Potsdam*, vol. xi., No. 36). He concludes that they show very decided traces of the effects of dispersion. Dr. Wilsing considered the deviations in the distance due to orbital motion of one of the components. Dr. Herman Davis has also examined these residuals (*Rutherfurd Photographic Measures, Parallax of* 61 *Cygni*), and is inclined to attribute them to a real difference of parallax of the two components. A comparison of the solutions of Kapteyn and Davis shows that the effects of atmospheric dispersion and of a real difference of parallax run so nearly parallel that it is impossible to discriminate between them. As a numerical corroboration of Professor Kapteyn's proposition the argument therefore fails; but the manner of its failure is itself the strongest proof of the truth of the proposition—Photographs for parallax must all be taken on the meridian, or, at least, in identical small hour angles.

This condition is not so completely prohibitive of parallax

determinations by photography as it may at first sight appear. But it requires generally that the plates shall be taken at some distance from the epochs of maximum parallactic displacement.

From a comparison of the measures made in reversed positions of the plate, the probable error of a parallax derived from one plate is $\pm 0''.0155$; whereas a comparison *inter se* of the results from three plates gives for the same quantity $\pm 0''.0315$. A number of investigations into the cause of this discrepancy lead to the conclusion that the agreement of successive pointings on one image is no criterion of the real accuracy of the measured position; that the true P.E. of pointing on a single image, four settings in each of two positions of the plate, is $\pm 0''.080$; and that consequently a single setting in each of two positions gives all the accuracy obtainable from a single plate. Finally, the real P.E. of a parallax derived from one plate is $\pm 0''.035$.

On the basis of these results Professor Kapteyn discusses the possibility of a general Durchmusterung for parallax, to include all stars down to the 10th magnitude, about 800,000 in number. From the results of an unpublished investigation it is probable that 450 of these have a parallax $\geqq 0''.10$. On the other hand, since the P.E. of a parallax derived from two plates is ± 0.025, the accumulation of accidental error would produce in 800,000 determinations some 6000 entirely spurious parallaxes $\geqq 0''.10$. It would be necessary to take further plates to separate the true from the false. With an expenditure of two more plates on every star for which the first determination gave a parallax $\geqq 0''.11$, about 500 real and well-determined parallaxes would eventually be obtained.

It is estimated that the total labour involved in the photographic work would be about equal to that expended on the chartand catalogue plates for the *Carte du Ciel*; while the labour of measurement and reduction would not much exceed that required for the measurement of the catalogue series and their reduction to corrected rectangular coordinates.

Several reasons at once present themselves for regarding the first conclusion as much too hopeful. The most weighty of these is the consideration that, in the uncertain climates in which most astronomical work has to be done, the labour of obtaining results at strictly limited seasons of the year and hours of the night—half of them very late hours—is beyond comparison more severe than straightforward labour on the astrographic chart.

There is, however, nothing to discourage at least a great extension of work on the lines which Professor Kapteyn has laid down; and there is every reason to hope that as the accuracy of the work will surely gradually increase, the large proportion of spurious parallaxes obtained will diminish.

In conclusion it may be permitted to congratulate Professor Kapteyn on the foundation of an astronomical laboratory and a school of practical astronomy in a university which possesses no

observatory, in the hitherto accepted sense of the word. It is a great step towards generating the power required to deal with the mass of material superabundantly produced by existing photographic telescopes. A. R. H.

The Astrographic Chart.

The fourth meeting of the Permanent Committee, which, if the initial meeting be included, was the fifth conference on the Astrographic Chart, was held in Paris in July. Directors of twelve * out of the eighteen participating Observatories attended, the absentees being the representatives of Helsingfors (through ill-health), Sydney, Melbourne, Santiago de Chile, La Plata, Rio de Janeiro. The three last named observatories appear to have abandoned the work, and the offers of Dr. Thome of Cordoba, and M. Enrique Legrand, representing an observatory which is to be established in Monte Video, to undertake the zones allotted to these observatories were received by the Committee. It is understood that Mr. Cooke, of the Perth Observatory, West Australia, has since agreed to take a share in the work, so that the following table shows the present arrangement of the zones and the progress in each at date 1900 June.

	Zone.	Number of fields assigned.	Number taken for cat.	Number taken for chart.	Number of cat. plates measured.
Greenwich	+90° to +65°	1149	1106	1076	608
Rome	+64 „ +55	1140	476	106	15
Catania	+54 „ +47	1008	1008	...	36
Helsingfors	+46 „ +40	1008	1008		380
Potsdam	+39 „ +32	1232	1232	...	250
Oxford	+31 „ +25	1180	736	...	736
Paris	+24 „ +18	1260	1260	97	650
Bordeaux	+17 „ +11	1260	402	17	293
Toulouse	+10 „ +5	1080	540	45	135
Algiers	+4 „ −2	1260	1260	56	497
San Fernando ...	−3 „ −9	1260	1260	664	145
Tacubaya	−10 „ −16	1260	746	...	203
Monte Video ...	−17 „ −23	1260	...	...	...
Cordoba	−24 „ −31	1360	...	...	...
Perth	−32 „ −40	1376	...	...	...
Cape of Good Hope	−41 „ −51	1512	1512	1134	106
Sydney	−52 „ −64	1400	1400		
Melbourne	−65 „ −90	1149	900	575	

* M. Vallé, who has lately succeeded to the Directorship of the Tacubaya Observatory, was present, as well as his predecessor M. Anguiano. Neither he, nor Dr. Thome, nor M. Legrand are included in this number. H. P. H.

The chart plates taken at Paris, Bordeaux, Toulouse and Algiers are being reproduced on an enlarged scale by heliogravure, and the numbers given for these observatories in column 5 of the above table refer to these reproductions; negatives of many other fields have been taken. The measurement of the catalogue plates taken at Sydney and Melbourne is being actively carried on at the Melbourne Observatory, but the number measured at the date to which the table refers is not to hand. At the end of the year 1899, 42 of the plates had been measured.

The substance of the chief resolution of the Conference is that it is not necessary that equatorial coordinates for all the stars should be given in the *Astrographic Catalogue*. It will be sufficient if it contains the measured rectangular coordinates of the stars with sufficient data to convert these into standard coordinates. Supplementary appendices or introduction can be be added as may be thought necessary. The printing of the *Greenwich Catalogue* on these lines is proceeding, and nearly a quarter of the whole work is in type. The *Paris Catalogue* is being printed in a very similar form. As to the publication of the *Chart*, it was resolved that copies on paper of the plates should be made, but no agreement as to the method was arrived at.

The Conference also discussed methods of measuring the diameters of the star images and also the length and method of exposure of the chart plates. It may be remembered that it had been resolved previously that half of these should be taken with three exposures of thirty minutes each, the others with one exposure of forty minutes. The procedure in both these matters was left to individual discretion.

Some papers relating to the subject have appeared in the Notices of the Society during the year. H. P. H.

Universal Time.

During the year two countries have been added to the number of those whose legal time depends on the meridian of Greenwich. Since October 1 Eastern-European Time, two hours fast on Greenwich, has been in use in Egypt, and the time-balls at Alexandria and Port Said have been dropped according to this. From 1901 January 1, Greenwich time has been the legal time in Spain, and the hours in this country are to be counted from 1 to 24, the day beginning at midnight.

It may be added that the Paris Bureau des Longitudes made a similar change in the *Annuaire* for 1900, and the words *matin* and *soir* no longer appear in that publication, but all times are described as *moyenne civile.* H. P. H.

The Cataloguing of Astronomical Literature.

On the initiative of the Royal Society, an International Conference was held in London in 1896 to consider the indexing of scientific literature. A resolution was carried, "That it is desirable to compile and publish, by means of some International organisation, a complete Catalogue of Scientific Literature, arranged according both to subject-matter and to author's names."

The Royal Society, later in the same year, appointed a committee to study all questions relating to the projected Catalogue, and two further International Conferences were held for the same purpose in 1898 and 1900. The difficulties attending the inception of this gigantic work seem now to have been overcome, and it is definitely settled that the Catalogue shall include all scientific literature published subsequently to 1901 January 1, and that publication shall commence with the volumes for the current year. Seventeen volumes are to be published annually, of which one will be devoted to astronomy, one to mathematics, one to botany, etc.; it is expected that they will contain an aggregate of 160,000 entries per annum. The materials out of which the Catalogue is formed are furnished to a Central Bureau in London by bodies termed Regional Bureaux, of which one is being established in every civilised nation. In this country the work of the Regional Bureau will be done by the learned societies, the Council of the R.A.S. having undertaken the work of furnishing slips for all the astronomical literature published in the United Kingdom.

The new *Astronomischer Jahresbericht*, edited by Dr. W. F. Wislicenus under the auspices of the *Astronomische Gesellschaft*, though very different in plan from the Catalogue, is largely designed to meet the same need. In an annual volume of about 500 pages, the astronomical papers published during the year preceding are briefly reviewed. The general arrangement is similar to that of the *Jahrbuch über die Fortschritte der Mathematik*, and the one publication will probably be found as useful to the astronomer as the other has long been to the mathematician.

E. T. W.

Papers read before the Society from March 1900 to January 1901.

1900.

Mar. 9. Observations of the *Leonids*, 1899. C. Michie Smith.

Photographic observations of Hind's variable Nebula in *Taurus*, made with the Crossley reflector of the Lick Observatory. J. E. Keeler.

Ephemeris for physical observations of the Moon for the second half of 1900. A. C. D. Crommelin.

Note on a possible occultation of *A Geminorum* by *Venus*, 1900 May 27–28. W. W. Bryant.

The maximum duration possible for a total solar eclipse. C. T. Whitmell.

The use of a coloured screen in photographing the corona during an eclipse. W. Shackleton.

On a simple method of comparing the Bonn Durchmusterung with photographic plates. H. H. Turner.

Graphical method for the determination of the local times of contact in a solar eclipse. F. C. Penrose.

Observations of *Saturn* made at Juvisy Observatory in 1899. C. Flammarion.

Apr. 11. On stationary radiants of meteors: reply to the criticisms of M. Brédikhine. H. H. Turner.

On the binary system of *Capella*. H. F. Newall.

Observations of spots and markings on the planet *Jupiter* made at the Dearborn Observatory of North-Western University, Evanston, U.S.A. G. W. Hough.

On the orbit of β 883. T. Lewis.

The effects of stellar rotation upon spectrum lines. A. Fowler.

The equatorial current of *Jupiter* in 1898. A. Stanley Williams.

On the alleged rotation of the spiral nebula *Messier* 51, *Canum Venaticorum*. H. H. Turner.

Observations of the *Leonids* made at the Cambridge Observatory on 1899 November 13, 14, 15. A. R. Hinks.

Measures of double stars from photographs taken with the 26-inch refractor of the Thompson equatorial at the Royal Observatory, Greenwich. Communicated by the Astronomer Royal.

1900.

April 11. Cometary observations at the Liverpool Observatory. W. E. Plummer.

An application of projective geometry to binary star orbits. H. C. Plummer.

Results of micrometer measures of double stars made with the 28-inch refractor at the Royal Observatory, Greenwich, in the year 1899. Communicated by the Astronomer Royal.

May 11. Observations of Minor Planets at Windsor, New South Wales. John Tebbutt.

The duration of the greater Sun-spot disturbances for the years 1881–99. Rev. A. L. Cortie.

Note on measures by Professor Barnard of two standard points on the Moon's surface. S. A. Saunder.

Micrometer measures of double stars. William Coleman.

On planning photographic observations of *Eros*. A. R. Hinks.

June 8. Note on a meteoric shower south of *Corvus*. W. F. Denning.

Theory of the motion of the Moon: Part III. Chapter VI. E. W. Brown.

The partial eclipse of the Sun, 1900 May 28, observed at Stonyhurst College Observatory. Rev. W. Sidgreaves.

The partial eclipse of the Sun, 1900 May 28, observed at Norwich. G. J. Newbegin.

Remarks on the total eclipse of the Sun, 1900 May 28, observed at Navalmoral, Spain. Rev. S. J. Johnson.

Inquiry as to the cause of the shadow bands upon the Earth which accompany total eclipses of the Sun. G. Johnstone Stoney.

The partial eclipse of the Sun, 1900 May 28, observed at Armagh. J. L. E. Dreyer.

The partial eclipse of the Sun, 1900 May 28, observed at Forest Lodge, Maresfield. Capt. W. Noble.

The partial eclipse of the Sun, 1900 May 28, observed at the Radcliffe Observatory, Oxford. Communicated by the Radcliffe Observer.

Notes on the total eclipse of the Sun, 1900 May 28, observed at Algiers. E. W. Maunder and A. C. D. Crommelin.

Observations of *Capella* as a double star made at the Royal Observatory, Greenwich. Communicated by the Astronomer Royal.

Description of the Durham Almucantar. R. A. Sampson.

Nov. 9. Ephemeris of *Eros*. Frank Robbins.

The partial eclipse of the Sun, 1900 May 28, observed at Col. Cooper's Observatory, Markree. F. W. Henkel.

1900.

Nov. 9. A possible explanation of the Sun-spot period. E. W. Brown.

Discovery and observations of Comet Brooks (*b* 1900). W. R. Brooks.

Nebulæ discovered at the Chamberlin Observatory, University Park, Colorado. H. A. Howe.

Observations of nebulæ made at the Chamberlin Observatory, University Park, Colorado. H. A. Howe.

Note on the formulæ for star corrections. P. H. Cowell.

Observations of the phenomena of *Jupiter's* satellites at Windsor, New South Wales, in the years 1898 and 1899. John Tebbutt.

Note on the accuracy of the star charts published by the French Observatories as reproductions of their plates for the Astrographic Chart. H. H. Turner.

On the appearance of *Saturn's* crape ring in 1900. E. M. Antoniadi.

Observations of *Jupiter* and his satellites made at Mr. Crossley's Observatory, Bermerside, Halifax, during the opposition 1899–1900. Joseph Gledhill.

Photographic measures of the Ring Nebula in *Lyra* and of the neighbouring faint stars. F. P. Leavenworth.

Ephemeris for physical observations of the Moon for 1901. A. C. D. Crommelin.

Note on the Moon's eclipse diameter. A. C. D. Crommelin.

The occultation of *Saturn*, 1900 September 3. Rev. S. J. Johnson.

On the disappearance from photographic films of star images, and their recovery by the aid of a chemical process. Isaac Roberts.

Note on the total eclipse of the sun, 1900 May 28, observed at Algiers. Rev. C. D. P. Davies.

Micrometric measures of the diameter of *Neptune* and distance and position-angle of the satellite, made with the 28-inch refractor at the Royal Observatory, Greenwich. Communicated by the Astronomer Royal.

Corrections to the Armagh Catalogue for 1840. J. L. E. Dreyer.

Occultations of *Saturn*, 1900 June 13 and September 3, observed at the Radcliffe Observatory, Oxford. Communicated by the Radcliffe Observer.

Mean areas and heliographic latitudes of Sun-spots in the year 1899, deduced from photographs taken at the Royal Observatory, Greenwich, at Dehra Dûn (India), and in Mauritius. Communicated by the Astronomer Royal.

1900.

Nov. 9. On the variable velocity of α Persei. H. F. Newall.

On the near approach of the planet *Eros* to a star (BD+48°, 759). F. A. Bellamy.

Dec. 14. On the connection between solar spots and earth magnetic storms. Rev. W. Sidgreaves.

Watch for the *Leonids*, 1900, at Markree Observatory. F. W. Henkel.

The diameter of the asteroid *Juno* (3), determined with the micrometer of the 40-inch refractor of the Yerkes Observatory; with remarks on some of the other asteroids.

The *Leonids*, 1900 November 14; observations made at Blackheath. E. M. Antoniadi and A. C. D. Crommelin.

The *Leonids*, 1900; observations at the University Observatory, Oxford. H. H. Turner.

Ephemeris for physical observations of *Jupiter*, 1901. A. C. D. Crommelin.

ζ *Herculis*. T. Lewis.

On the magnitude of the wide companion of ζ *Lyræ*. Rev. S. J. Johnson.

The *Leonids*, 1900; observations made at the Radcliffe Observatory, Oxford. Communicated by the Radcliffe Observer.

On observations of *Capella* as a double star made at the Royal Observatory, Greenwich. W. H. M. Christie.

1901.

Jan. 11. Observations of the *Leonid* meteors of 1900, made at the Royal Observatory, Greenwich. Communicated by the Astronomer Royal.

On mechanically compensating the rotation of the field of a siderostat. H. H. Turner.

On the accuracy of eye observations of meteors, and the determination of their radiant points. Bryan Cookson.

Leonids observed at Cambridge Observatory, 1900 November 13, 14, 15. J. C. W. Herschel.

On a method of reducing occultations of stars by the Moon; together with the reduction of occultations observed on three occasions at the Liverpool Observatory. H. C. Plummer.

Observations of *Saturn* made at Juvisy Observatory in 1900. C. Flammarion.

Note on the rotation period of *Saturn* in 1896 and 1897. C. Flammarion.

The light curve of *S Aræ*. A. W. Roberts.

1901.

Jan. 11. Observations of occultations of stars and *Saturn* by the moon made at the Royal Observatory, Greenwich, in the year 1900. Communicated by the Astronomer Royal.

Observations of the solar eclipse of 1900 May 28, made at the Royal Observatory, Greenwich. Communicated by the Astronomer Royal.

List of Public Institutions and of Persons who have contributed to the Library, &c., since the last Anniversary.

Her Majesty's Government in India.
The Lords Commissioners of the Admiralty.
The Italian Government.
The Norwegian Government.
British Association for the Advancement of Science.
British Astronomical Association.
British Horological Institute.
Camera Club.
Chemical Society.
Geological Society of London.
London Mathematical Society.
Meteorological Office.
Physical Society of London.
Royal Geographical Society.
Royal Institution of Great Britain.
Royal Meteorological Society.
Royal Observatory, Greenwich.
Royal Photographic Society of Great Britain.
Royal Society of London.
Royal United Service Institution.
Society of Arts.
University College, London.
Belfast Natural History and Philosophical Society.
Birmingham Natural History and Philosophical Society.
Cambridge Philosophical Society.
Cambridge University : Adams Memorial Committee.
Cardiff, Astronomical Society of Wales.
Dublin, Royal Irish Academy.
Dublin, Royal Society.
Dunsink Observatory.
Edinburgh, Royal Society.
Kew Observatory.
Leeds Astronomical Society.
Leeds Philosophical and Literary Society.
Liverpool Literary and Philosophical Society.
Liverpool Observatory.
Manchester Literary and Philosophical Society.
Oxford, Radcliffe Observatory.

Oxford, University Observatory.
Rugby School Natural History Society.
Stonyhurst College Observatory.
Truro, Royal Institution of Cornwall.
Adelaide, Government Observatory.
Amsterdam, Royal Academy of Sciences.
Arcetri, Royal Observatory.
Athens, National Observatory.
Baltimore, Johns Hopkins University.
Basel Astronomical and Meteorological Institute.
Basel University.
Batavia, Royal Magnetical and Meteorological Observatory.
Batavia, Natural History Society of Netherlands-India.
Belgium, Royal Observatory.
Berlin, Central International Geodetic Bureau.
Berlin, German Physical Society.
Berlin, Institute of Computation of the Royal Observatory.
Berlin, Royal Prussian Academy of Sciences.
Berne University.
Bogotà Observatory.
Bombay Branch of the Royal Asiatic Society.
Bonn, Royal Observatory.
Bordeaux, Society of Physical and Natural Sciences.
Boston, American Academy of Arts and Sciences.
Buda-Pesth, Hungarian Academy of Sciences.
Buda-Pesth, Royal Hungarian Institute for Meteorology and Terrestrial Magnetism.
Calcutta, Asiatic Society of Bengal.
Canada, Geological Survey.
Canada, Royal Society.
Cape of Good Hope, Royal Observatory.
Cape Town, South African Philosophical Society.
Catania, Italian Spectroscopic Society.
Catania, Royal Observatory.
Cherbourg, National Academy of Sciences.
Chicago Academy of Sciences.
Christiania, Norwegian Meteorological Institute.
Copenhagen, Royal Danish Academy of Sciences.
Cordoba, Argentine Meteorological Office.
Cordoba, Argentine National Observatory.
Cracow, Academy of Sciences.
Dijon, Academy of Sciences.
Dorpat, Imperial Observatory.
Egypt, Survey Department.
Geneva Observatory.
Göttingen, Royal Society of Sciences.
Göttingen, Royal Observatory.
Groningen, Astronomical Laboratory.
Halifax, Nova Scotian Institute of Sciences.
Hamburg Observatory.

Harvard College Astronomical Observatory.
Heidelberg Observatory.
Helsingfors, Society of Sciences of Finland.
Hobart, Royal Society of Tasmania.
Hong Kong Observatory.
International Committee of Weights and Measures.
Italian Meteorological Society.
Kasan, Imperial Observatory.
Kasan, Imperial University.
Kiel, Royal Observatory.
Königsberg, Royal University Observatory.
Leiden Observatory.
Leipzig Astronomical Society.
Leipzig, Prince Jablonowski Society.
Leipzig, Royal Society of Sciences of Saxony.
Lick Observatory.
Lisbon, Royal Astronomical Observatory.
Lund, Astronomical Observatory.
Madras, Government Observatory.
Madrid Observatory.
Madrid, Royal Academy of Sciences.
Manila Observatory.
Mauritius, Royal Alfred Observatory.
Melbourne, Government Observatory.
Milan, Royal Observatory.
Moncalieri Observatory.
Montpellier, Academy of Sciences.
Moscow, Imperial Society of Naturalists.
Munich, Royal Bavarian Academy.
Naples, Academy of Physical and Mathematical Sciences.
Natal Observatory.
New York, Columbia College Observatory.
Nice Observatory.
O-Gyalla, Central Meteorological and Magnetical Observatory.
Ottawa, Scientific and Literary Society.
Padua Observatory.
Paris, Academy of Sciences.
Paris, Astronomical Society of France.
Paris, Bureau of Longitude.
Paris, Mathematical Society of France.
Paris Observatory.
Paris, Philomathic Society.
Perth Observatory, Western Australia.
Philadelphia, American Philosophical Society.
Philadelphia, Franklin Institute.
Pola, Imperial Hydrographic Office.
Pola, Meteorological and Magnetical Observatory.
Potsdam, Central International Geodetic Bureau.
Potsdam, Royal Prussian Geodetic Institute.

Poughkeepsie, Vassar College Observatory.
Poulkowa Observatory.
Prague, Imperial Observatory.
Queensland Branch of the Geographical Society of Australasia.
Rio de Janeiro Observatory.
Rome, Pontifical Academy *de' nuovi Lincei.*
Rome, Royal Academy *dei Lincei.*
St. Petersburg, Imperial Academy of Sciences.
St. Petersburg, Russian Astronomical Society.
San Fernando Observatory.
San Fiel College, Portugal.
San Francisco, Astronomical Society of the Pacific.
Stockholm, Royal Swedish Academy of Sciences.
Sydney, Royal Society of New South Wales.
Tachkent, Astronomical and Physical Observatory.
Tacubaya, National Astronomical Observatory.
Toronto, Astronomical and Physical Society.
Toronto, Canadian Institute.
Toulouse, Astronomical Observatory.
Turin, Royal Academy of Sciences.
Turin, Royal Astronomical Observatory.
United States Coast and Geodetic Survey.
Upsala, Royal Society of Sciences.
Vienna, Imperial Academy of Sciences.
Vienna, Imperial Austrian Geodetic Bureau.
Vienna, Imperial Ministry of Marine.
Warsaw Astronomical Observatory.
Washington, National Academy of Sciences.
Washington, Office of the American Ephemeris.
Washington, Smithsonian Institution.
Washington, United States Naval Observatory.
Yerkes Observatory.
Zürich, Central Meteorological Institute of Switzerland.
Zürich, Society of Natural History.
Editors of the "American Journal of Mathematics."
Editors of the "American Journal of Science."
Editor of the "Astronomical Journal."
Editor of the "Astronomische Nachrichten."
Editors of the "Astrophysical Journal."
Editor of the "Athenæum."
Editors of the "Bulletin des Sciences Mathématiques."
Editor of the "English Mechanic."
Editor of "Himmel und Erde."
Editor of "Indian Engineering."
Editor of the "Naturwissenschaftliche Rundschau."
Editors of "The Observatory."
Editors of "Popular Astronomy."
Editor of "Sirius."

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ADDRESS

Delivered by the President, Mr. E. B. Knobel, on presenting the Gold Medal of the Society to Professor E. C. Pickering.

The Council have awarded the gold medal to Professor Edward Charles Pickering "for his researches on Variable Stars and his work in Astronomical Photography," and it is now the recognised duty of your President to submit to you some of the considerations which have actuated them in selecting the distinguished Director of Harvard College Observatory as the recipient of their highest honour.

In attempting to lay before you an outline of the work of our Medallist in the above directions, I am very conscious of the great difficulties attendant upon an adequate presentation of the claims of an astronomer who, combining enthusiasm with devotion, and fertility in resource with surpassing skill, possesses in an eminent degree a comprehensive intellect to disentangle and elucidate, coupled with a power of organisation to carry his enterprise to a successful issue.

It may be truly said that the successful practical astronomer of the present day must possess much greater versatility in his qualifications, and more varied knowledge of the kindred sciences, than would a generation back have been deemed adequate for profound research. The striking advance witnessed during the latter part of the nineteenth century in novel devices in the construction of astronomical instruments, the enormous power for advancing knowledge which has accrued from the development of spectroscopy and photography, have all brought additional claims upon the energy and intelligence of the modern astronomer, which, to ensure success, have to be satisfied and fulfilled.

The study of the extensive researches and varied observations of our Medallist reveals the lucid and vigorous mind that has been applied to the solution of so many difficult problems, and demonstrates the skill and energy which have enabled him to obtain a complete mastery over the processes necessary for the accomplishment of his designs.

The long series of volumes of the *Annals of Harvard College Observatory* published in the past twenty-five years record a wealth of original research far beyond the limits of an address to

epitomise. On a former occasion the occupant of this chair addressed you on the splendid work accomplished by Professor Pickering in stellar photometry, and I shall hope later on to make some reference to his more recent researches in this direction. There is obviously no finality in astronomical observation, and Harvard teaches us that whether it be a photometric or a photographic survey of the heavens, the work is repeated and revised again and again to correct errors and to record changes and variability which might otherwise escape notice.

Professor Pickering's researches on variable stars date from the commencement of his directorship of Harvard Observatory in 1876. In his first annual report he announces his intention to undertake the extensive work of reducing Argelander's comparative observations of variable stars, by measuring the brightness of the comparison stars, and thus to determine the true brightness of the variables as given in the immense mass of Bonn observations—a work which he published some years later.

His first paper on the subject was published in 1880, wherein from careful mathematical reasoning he proves that the variability of stars of the *Algol* type is due to a non-luminous body revolving round the star; and the results he obtained for the ratio of the diameters of *Algol* and its satellite are very closely accordant with those announced by Vogel nine or ten years later from the Potsdam spectroscopic observations.

A further memoir, which appeared the following year, is extremely suggestive. In considering those variable stars whose light is continually varying, but whose changes are repeated with great regularity in a period not exceeding a few days, his reasoning is of this form :—

Admitting a common origin of the stars of the *Milky Way*, a general coincidence in their axes of rotation is not improbable, especially as such an approximate coincidence occurs in the members of the solar system. If the coincidence were exact, the direction must be that of the poles of the Sun, or approximately that of the pole of the ecliptic. On the other hand, since the stars of the *Milky Way* are supposed to be arranged in the general form of a flattened disc, we should more naturally expect that the axes of rotation would be symmetrically situated with regard to it, or would coincide with its shortest dimension. According to this theory, the axes of rotation would be directed towards the poles of the *Milky Way*.

If we suppose that a great number of variable stars were distributed over the heavens, it is evident that those seen in the direction of their axes would not appear to vary, since, as they turned they would always present the same portions of their surfaces to the observer. Those at right angles to this direction would show the greatest variation, and would appear to be more numerous, since they would be more likely to be detected. If, then, the axes are coincident, we should expect that most of these variable stars would lie along the arc of a great circle, whose

pole would coincide with their axes of rotation. As a fact, eighteen such variable stars are found to be in a great circle very nearly coincident with the *Milky Way*. And upon this result Professor Pickering sagaciously indicates a method of discovering variable stars of this class by observation of certain parts of the sky.

Numerous early papers on variable stars must necessarily be passed over on the present occasion, but in this domain of observational astronomy it may be interesting to give an example of the indefatigable assiduity of our medallist.

In a photometric study of *β Persei*, he records having made on thirteen nights 2748 comparisons with the neighbouring star *ω Persei*, of which six hundred were made in a single night. On that occasion the observations were continued almost without intermission for $8\frac{3}{4}$ hours. Again, in a similar study of Ceraski's Variable (D. M. 81°—25), he made 3276 comparisons on five evenings, of which nine hundred were obtained on a single night, the probable error of a single minimum determined in this way being only 1·3 minutes.

It was, of course, the development of the photometers he had devised and perfected with so much skill that permitted the acquirement of such a mass of observations, and from the above quotation it would seem that quick-firing weapons are as necessary for attacking celestial problems as for some others of a less peaceful nature.

The study of variable stars is obviously a photometric research, and allusion should therefore be made to some of the more recent processes employed by Professor Pickering in his work. Herein it is noteworthy to mention his ingenious adaptation of Professor Pritchard's Wedge Photometer, to be used as a transit photometer for determining the magnitudes of stars too faint to be measured by the Meridian Photometer. This instrument consisted of an ordinary wedge of tinted glass cemented to a glass plate carrying an opaque bar parallel to the thinner end of the tinted wedge. The plate is placed in the focal plane of the telescope, and the bar is made coincident with an hour circle. The interval between the transit of a star across the bar and its disappearance in the wedge is the observed quantity from which the brightness of the star is deduced. The thirteenth volume of the *Harvard Annals* contains a catalogue of 4143 stars from the 8th to the 14th magnitude, whose brightness was determined by this most ingenious arrangement.

It was at Harvard College Observatory that the birth of stellar photography took place in the year 1850, when Bond and Whipple succeeded in obtaining satisfactory images of bright stars on a daguerreotype plate. It was natural, therefore, that Professor Pickering should early avail himself of the immense aid to astronomy afforded by the invention of the photographic dry plate to assist his researches on variable stars and stellar photometry.

In a highly interesting memoir on stellar photography published in 1886, he pointed out that the different photometric processes which hitherto had been used in determining the light of the stars, give results which differ systematically when large variations in light are to be measured. This is not due to a difference in the assumed value of the unit of the scale of magnitudes, but to an actual difference in the measurement of the amount of light. He suggests that photography affords an excellent means of determining systematic differences in photometric catalogues, as the errors in that case will be of a very different kind. To carry this into effect, he points out the advantages that will accrue from photographing stars without moving the telescope. Thus each star by the diurnal motion will form a trail upon the plate. Such trails will appear as lines whose intensity is perfectly uniform within the limits of accuracy of which the comparison is capable; and he found that small differences in light are much more perceptible in the trails than in the circular images obtained when the telescope is driven by clockwork. In his hands this original method assumes a considerable scientific value. For the brighter stars, even when near the Equator, a trail is formed when the camera is stationary; for others less bright the duration of the transit can be regulated as need requires. It is obvious that as the stars approach the pole the trails made during a given exposure become shorter, and the photographic action is lengthened, so that when the camera is pointed to the pole trails of stars as low as the 14th magnitude can be easily photographed.

The method of trails was applied not only to the photometry of stars, but also in a most interesting and instructive way in photographing stellar spectra, referred to later on.

The mode of determining the magnitudes from trails was to compare the trail of a star whose brightness had been obtained in various ways, with the trails of those stars whose magnitude was sought. Obviously there must be systematic differences in the magnitudes of stars determined by visual and by photographic methods, and the comparisons instituted clearly indicated such differences. The evidence showed that for stars brighter than the fifth magnitude the numerical photographic magnitudes are in excess of the photometric magnitudes by one unit, and in faint magnitudes the reverse condition holds, as is possible from other considerations which cannot well be dwelt upon here. In an exhaustive discussion, Professor Pickering indicates the many advantages presented by this interesting method for determining not only the brightness but also the position of stars.

In endeavouring to give you some idea of the skill, vigour, and enterprise which characterise our Medallist, I would now pass to that magnificent work which has been organised and carried into such successful execution by him, under the title of the Henry Draper Memorial—a work which has given some of the most brilliant results for our admiration.

The numerous researches undertaken at Harvard College Observatory have needed not only a corps of highly skilled observers, but also an array of instruments of various kinds and various calibres; all for their efficient use requiring considerable funds. To the great honour of Professor Pickering's countrymen and countrywomen, the value of his researches has been perceived and justly appreciated, and by means of much generous pecuniary assistance he has been enabled to accomplish schemes which he rightly considered would advance our science.

But this, we are happy to recognise, is not singular in a land where there is such keen appreciation of all enlightened and intellectual methods, where there is continual striving towards high ideals in philosophy and science, and where there are so many generous benefactors ready to give princely sums to found colleges, to establish observatories, and to encourage in every way the pursuit and advancement of knowledge.

The work alluded to above has been effected by the liberal provision made by Mrs. Draper in 1886 for carrying on researches in Stellar Spectroscopy, as a memorial to her late husband, Professor Henry Draper, who was so successful a worker in the new lines of research which the development of the spectroscope and of photography had opened out.

Her beautiful idea was framed to embrace a complete discussion of the constitution, the conditions and the physical properties of the stars as revealed by their spectra. It is difficult to conceive a more appropriate way of hallowing the memory of a distinguished man, than by efforts to enlarge and enrich the science in which he laboured and to which he was so devoted. Accordingly, in placing that trust in Professor Pickering's hands, he was supplied with instruments suitable for the undertaking, and with funds sufficient to enable him to carry the work into execution.

The results hitherto published are contained in three volumes of the *Harvard Annals*, besides numerous circulars and shorter papers describing specific discoveries. The investigations were planned to cover the entire sky, and when, in the course of a few years the scheme was fully developed, four telescopes were established for the observations—two at Cambridge for the northern hemisphere, and two at Arequipa, in Peru, at an altitude of 8000 feet, for all stars too far south to be observed at the former observatory. The principal instrument at each station was an 8-inch photographic doublet of large angular aperture and short focal length, permitting photographs to be obtained extending over a region 10° square. In addition to these, an 11-inch refractor was employed at Cambridge and a 13-inch at Arequipa. The dispersion in all cases was obtained by one or more prisms over the object-glass, which could be conveniently removed to allow of the instrument being used for ordinary stellar photography.

The magnificent volume which embodies the principal results

has been appropriately entitled *The Draper Catalogue.* When we learn that herein are contained the details of the spectra of 10,351 stars, deduced from the measurements of 28,266 spectra, we can form some idea of the magnitude of Professor Pickering's operations, and appreciate his inspiriting influence on all those who so ably assisted him in completing this portion of the work. Particularly is it interesting to see the important part of the work undertaken by lady assistants, one of whom—Mrs. Fleming—is entitled to our gratitude, as from her minute and accurate examination of the photographs she has been able to announce some of the most interesting discoveries in variable stars and stars with peculiar spectra that have been recorded.

In photographing the spectra, the prism with a reflecting angle of 13° was adjusted so that its refracting edge was placed perpendicular to the axis of the earth. The spectrum of the star formed a line on the plate; then, by altering the rate of the driving clock this line was allowed to trail slowly over the plate to give an image of a desired width. By this elegant means spectra were obtained of all stars down to the seventh magnitude, of such dimensions that they could be studied and classified. Hitherto the method of using a narrow slit, supplemented or not by a cylindrical lens, and requiring extreme accuracy in the driving clock, and even then a continued personal vigilance for the manual correction of its irregularities, has proved a most serious drawback in the register of stellar spectra by the aid of photography. By the method of trails, the slit, the cylindrical lens, and the painful watching are dispensed with, and, as has been well remarked, "the light of the star itself, by diurnal motion, becomes virtually a line of light or illuminated slit, which is dispersed into its spectrum by the refracting prism." We may well admire the beauty and simplicity of this method, so essentially practical, and so capable of yielding a mass of results available for leisurely study. It undoubtedly marks a distinct advance in photographic astronomy.

The spectra in *The Draper Catalogue* are classified in an original and somewhat minute manner. Secchi's type I., the Sirian stars, are subdivided into four varieties. The solar stars, type II., into eight varieties. The third type is not subdivided, and it would seem that the difference between this and the second type is much less marked in the photographic than in the visible portion of the spectra. The fourth type of red stars are absent. A separate classification is given to stars with bright lines, and planetary nebulæ, which Professor Pickering considers as together forming a fifth type.

One remarkable result appears from the study of this valuable catalogue. Practically two-thirds of Milky Way stars are found to be Sirian stars, belonging to type I., thus confirming to a certain extent Kapteyn's discovery that "stars of the Milky Way are in general bluer than the stars in other regions of the sky;" in other words, that they are photographically more brilliant.

In Professor Pickering's careful discussion of every feature of *The Draper Catalogue* one is rather bewildered by the multitude of original and far-seeing thoughts deduced from the study of the spectra of the whole heavens. One striking conclusion may be here mentioned : that, with few exceptions, all the stars may be arranged in a sequence, beginning with the planetary nebulæ, passing through the bright-line stars to the *Orion* stars, thence to the first type, and by insensible changes to the second and third type stars ; and he adds, "the evidence that the same plan governs the construction of all parts of the visible universe is thus conclusive."

But what has already been published in *The Draper Catalogue* does not represent one-half of what has been accomplished ; for we learn that there exists, as yet unpublished, a second *Draper Catalogue*, giving the spectra of 30,000 stars down to the eighth magnitude, from the north to the south pole, a mass of material from which we may anticipate many valuable lessons and unexpected discoveries.

One of the principal objects of the Henry Draper Memorial was to investigate the physical constitution of the stars, and in the first instance their relative magnitudes. For this purpose photographs of three kinds were obtained—viz. trails, circular images, and spectra. The first of these has already been alluded to. In the second method, when the telescope was driven by clockwork to give circular images, the scale for determining magnitudes was obtained by taking a series of exposures on a given cluster of stars, moving the telescope slightly in right ascension after each one. Professor Pickering had found that Pogson's ratio of 2·5 for a difference of one magnitude was too low for photographic magnitudes, and that three times the exposure would bring the results more in accord with visual magnitudes. Accordingly, each exposure in the above series was one-third less than that preceding, and thus the scale for comparison was formed.

With regard to the determination of relative magnitudes from the spectra, the very original and interesting plan was adopted of comparing the density of the photographed spectra in the vicinity of the G line with a prepared scale of densities. The measurement of relative brightness between two stars differing materially in colour is very imperfectly obtained by visual methods. Indeed, Wilhelm Struve doubted whether it would ever be possible for photometry to decide which was the brighter of two stars differing in colour, such as *Arcturus* and *Vega*. The ingenious method of Professor Pickering, though it is limited to measuring the brightness of stellar light of a particular refrangibility, is nevertheless a most important step in a new direction for comparing magnitudes, and opens out some interesting ideas for our consideration. In addition to what we have already in our hands, Professor Pickering has prepared the material for an investigation of the photographic brightness of 40,000 standard

stars of about the tenth magnitude, which we hope may shortly be given to the world.

The discussion and comparison he subsequently undertakes, of different methods of ascertaining the brightness of stars, shows naturally very conflicting results; and he concludes that the determination of the true relative brightness of the stars, either visually or photographically, is a much more difficult problem than would appear at first sight. It must be left to future investigators to decide which of the various processes employed gives the correct result. The spectra in *The Draper Catalogue* were all photographed with the 8-inch telescopes and were on a small scale. For bright stars the 11-inch telescope was used, giving spectra on a much larger scale—the results of which are published in a separate volume, and discussed by Professor Pickering with his usual acumen. At Arequipa similar work was undertaken with the 13-inch telescope.

The 8-inch telescopes were also employed in star charting. With these instruments photographic charts of the entire sky from the north to the south pole have been obtained every year, showing all stars brighter than the thirteenth magnitude.

The photographs obtained up to the present time by the four telescopes employed in the Henry Draper Memorial amount to the astounding figures of 52,229 plates taken with the two 8-inch telescopes, 12,872 with the 11-inch, and 10,214 with the 13-inch. When we bear in mind that these figures signify repeated surveys of the whole heavens—spectrographic, photometric, and photographic—extending continuously over several years, we cannot fail to realise the enormous treasure thus stored up for us by the Harvard Observatory.

The resources at Professor Pickering's disposal were very materially increased in the year 1889 by the generous gift of a large sum of money from Miss Bruce, of New York, for a 24-inch photographic telescope, "to be used under favourable climatic conditions in such a way as in the judgment of Professor Pickering would best advance astronomical science."

The establishment of a branch of Harvard College Observatory in the southern hemisphere, at the high altitude of Arequipa, in Peru, is a conspicuous instance of the Director's foresight of the necessities of modern astronomy to reduce the climatic difficulties of low-lying stations; and it was also a magnificent and unique idea to bring the whole stellar universe thus within his grasp. Accordingly, when the Bruce telescope was constructed, it was mounted at Arequipa, where it has been in regular use on special lines of research. Up to last year nearly 5000 photographs had been taken with it of planets, asteroids, nebulæ, and particular star fields.

One triumph of this telescope has already been announced by Professor William Pickering in the apparent discovery of a new satellite to the planet *Saturn*. This object is extremely small and faint, and we await at the moment confirmatory observations.

Among so many noteworthy features of our Medallist's work, there is, perhaps, no one more remarkable than the exceedingly ingenious instrument he invented for automatically charting the heavens. This instrument automatically photographs all stars down to the sixth magnitude as they transit during the night. It consists of a doublet of 6 inches aperture and about 2 feet focal length, mounted so as to make a complete circle of the meridian every twenty-one minutes. A clock automatically starts the movement, and the camera revolves in steps of 2° every two seconds until it has completely covered the meridian, an operation which takes six minutes. After an interval of a quarter of an hour the operation is repeated. At the end of three hours, during the half revolution, when the instrument is pointing to the Earth, the plate is shifted automatically, and the instrument got ready for the next exposure. The two seconds exposure is enough to photograph all stars down to the sixth magnitude, and all these are registered on the plate. Any new star or remarkable variable rising above the sixth magnitude, or any comet of equal brightness, would be recorded on these plates. Truly the ingenuity of such an arrangement must claim our interest and admiration.

To turn now to the discoveries that have resulted from these various researches, we do not find that that admiration is in any way limited.

The classification of stars according to their spectra is so far-reaching that Professor Pickering thinks it should be applied to each of their other properties. Of the variable stars, it appears, as we have said, that all known *Algol* stars have spectra of the first type, while long-period variables in general are of the third type, and have the hydrogen lines bright when near their maxima. This property has led to the discovery of numerous objects of this class, and no exception has been found of a star having this spectrum whose light does not really vary. Up to 1893 twenty new variable stars had been so discovered. Again, in variables of long period discovered visually, over forty have the hydrogen lines bright. Of such long-period variables, however, his photographic discoveries transcend those made visually. Some 150 of these variables have been discovered from the photographic plates, and the measurements and reductions of at least one-third have already been completed from about 100 plates of each star.

The Harvard circulars from 1895 to the present time contain numerous announcements of discoveries of variable stars from the examination of their spectra. The accounts are surprising indeed. Peculiarities in the spectrum of a particular star attract the attention of that most careful observer, Mrs. Fleming. Eighty-seven photographs of that region during the previous nine years are examined without trace of the star; then it appears in eight more recent photographs, and the existence of a new star is established. Or, if we take the case of a new *Algol* variable being discovered elsewhere, Professor Pickering immediately finds that

that region had been covered by 195 plates, all showing the spectrum of the star in varying degrees of brightness, and enabling the period of variability to be determined with a probable error of only one or two seconds. The minor planet *Eros* was discovered by Witt on 1898 August 13, but the examination of the Harvard photographs enabled Professor Pickering to announce that it could be detected on fifteen or sixteen plates taken from 1893 to 1896, and that the spectrum photographed in January 1894 was, like that of other planets and the Sun, of the second type. A remarkable photograph taken in February 1894 shows the planet as a long trail, while the images of stars are round. An ingenious method of photographing this planet when it was too faint to be observed in other ways was adopted last year. An eyepiece was connected with the photographic plate by means of a micrometer screw. A star was followed by means of the eyepiece, while a motion equal to that of *Eros* was given to the plate. On the plates the stars formed trails, while *Eros* appeared as a circular image.

Fourteen new stars have been discovered since 1572, when Tycho discovered the celebrated one in *Cassiopea*. Four of these were discovered by the Harvard photographs, viz. *Nova Normæ*, *Nova Carinæ*, *Nova Centauri*, and *Nova Sagittarii*, and in proof of this Professor Pickering has submitted copies of his photographs of the regions at different dates, showing in each case on the latter date a bright star which was non-existent at the earlier. With regard to the new star discovered by Anderson in February 1892 in the constellation *Auriga*, commonly called *Nova Aurigæ*, the earliest records are found upon the Harvard plates.

Eighteen photographs of the region taken with one of the 8-inch telescopes from November 1885 to November 1891 showed no trace of the star, though stars of the thirteenth magnitude were visible; but on plates exposed December 16 1891 to January 31 1892 the *Nova* is clearly shown as a fifth magnitude star. With the automatic instrument described above, plates were exposed on the region from October 21 to December 1, 1891, without indicating the *Nova*, but those exposed by the same instrument December 10 1891 to January 20, 1892, exhibit the new star quite clearly. That is to say, it was distinctly photographed by Professor Pickering six or seven weeks before its discovery by the Edinburgh astronomer.

Again, eight photographs taken in 1887 show a star in *Perseus* with bright hydrogen lines. No trace of such star is found in eighty-one photographs taken in the subsequent eight years. It is therefore proved that a new star blazed out in *Perseus* in the year 1887, which would have eluded observation altogether but for these priceless Harvard records.

Perhaps there is no more surprising discovery due to the organisation of the Henry Draper Memorial than that announced by Professor Bailey, the astronomer in charge of the Arequipa Observatory, that numerous globular clusters contain an extra-

ordinary number of variable stars. In the dense cluster *ω Centauri* there are 128 variable stars; in Messier 3, 132; in Messier 5, 85; and in Messier 15, 51. And as proof of the exhaustless manner in which such remarkable discoveries are investigated, we learn that Professor Pickering is already preparing for the press a series of 30,000 observations of the variable stars in the cluster *ω Centauri* alone.

The Arequipa photographs, from the careful examination of Mrs. Fleming, reveal that there are numerous stars which have peculiar spectra unlike any other stars. The spectra contain lines which are apparently due to some elements quite unknown in other stars, or on the Earth, and we have here a new field opened out for research.

These interesting discoveries afford food for prolonged study and consideration, but one result of the boundless energy of Professor Pickering is to forestall future discovery. No one will be able to claim the discovery of a new variable, or a new star, until he has satisfied himself that Harvard has not anticipated him by its numberless photographic records. All the more honour, however, to that observatory that it should have laid up stores of such valuable photographs, the examination of which cannot but increase our knowledge of the nature and distribution of the stars, and expand our ideas of the construction of the heavens.

The consideration of Professor Pickering's work in astronomical photography would not be complete without some, though on this occasion very brief, mention of his interesting photographic determination of the laws of atmospheric absorption—a question of capital importance in the photometric researches already alluded to. By photographing the trails of stars at upper and lower culmination on the same plate, with a certain system of exposures, data were obtained capable of yielding a value for the coefficient of absorption in fair agreement with determinations previously made with the Meridian Photometer.

It remains for me to say one word respecting our Medallist's recent work with the Meridian Photometer. Not only has the work known as the *Harvard Photometry* been completely revised and the magnitudes re-measured, but the same instrument as used in some of the earlier observations, was sent to Peru, and in the capable hands of Professor Bailey it was used to determine the photometric magnitudes of the whole of the southern hemisphere in the same way as it had been employed for the northern.

Thus, Professor Pickering has completed a photometric survey on a uniform plan of the whole heavens, involving a million observations; and, as we already know, he has also accomplished a photographic determination of brightness with uniform instruments for both hemispheres.

I venture to sum up his work in the following citation, which

expresses in far better words than I can employ the abstract of his labours :—

"Harvard College Observatory is a wonderful focus of activity, in which one hardly knows whether he ought most to admire the exhaustless energy or the admirable ingenuity which he finds displayed in it. Its work has been aided by gifts which have no parallel in the liberality that prompted them. Yet without energy and skill such gifts would have been useless. The activity of the establishment includes both hemispheres. Time would fail to tell how it has not only mapped out important regions of the heavens from the north to the south pole, but analysed the rays of light which come from hundreds of thousands of stars by recording their spectra in permanence on photographic plates. The work of the establishment is so organised that a new star cannot appear in any part of the heavens, nor a known star undergo any noteworthy change, without immediate detection by the photographic eye of one or more telescopes—all-seeing and never-sleeping policemen—that scan the heavens unceasingly while the astronomer may sleep, and report in the morning every case of irregularity in the proceedings of the heavenly bodies."

Time, however, will not permit me to offer all the evidence that might be adduced in support of the plea I have been urging. The task of doing full justice to a multitude of researches, so varied and original, and so replete with interest, is a very difficult one; but notwithstanding this inadequate and imperfect presentment of the labours of our illustrious Associate, I trust I have at least succeeded in satisfying you that he has fully merited the recognition the Council have accorded him.

The history of the award of the Gold Medal is the history of men who have made an indelible mark in astronomy—whose labours have stimulated and pioneered others in the path of success, and whose disciples have expanded and developed the principles which they enunciated, to the realisation of such progress in astronomical science as we are witnessing at the commencement of the twentieth century. Among such a roll of distinguished men, Professor Pickering will surely take an honourable place, as a brilliant leader, who, with rare skill, unwearied energy, and consummate ability, has known so well how to instigate, how to organise, and how to accomplish.

The President, addressing the American Ambassador, said :

Mr. Choate, I beg to thank your Excellency for the honour you have done the Royal Astronomical Society this day in so kindly appearing here to represent the distinguished Director of Harvard College Observatory.

In handing you this medal for conveyance to Professor Edward Charles Pickering, I beg you to assure him of our high

appreciation of his remarkable labours in stellar astronomy, and our continued interest in the important institution he so ably directs. We do not suppose that one who has displayed an unwearied activity throughout his whole career can need any such stimulus to nerve him to increased efforts for the advancement of our science; we only trust he will believe that, in offering him the highest honour in our power, we feel that we shall be equally honoured by his acceptance of it.

The meeting then proceeded to the election of Officers and Council for the ensuing year, when the following Fellows were elected :—

President.

J. W. L. GLAISHER, Esq., M.A., Sc.D., F.R.S.

Vice-Presidents.

W. H. M. CHRISTIE, Esq., C.B., M.A., F.R.S., Astronomer Royal.
A. A. COMMON, Esq., LL.D., F.R.S.
E. B. KNOBEL, Esq.
H. H. TURNER, Esq., D.Sc., F.R.S., Savilian Professor of Astronomy, Oxford.

Treasurer.

W. H. MAW, Esq.

Secretaries.

F. W. DYSON, Esq., M.A.
E. T. WHITTAKER, Esq., M.A.

Foreign Secretary.

Sir WILLIAM HUGGINS, K.C.B., LL.D., D.C.L., P.R.S.

Council.

Sir WILLIAM ABNEY, K.C.B., D.Sc., D.C.L., F.R.S.
Sir R. S. BALL, M.A., LL.D., F.R.S., Lowndean Professor of Astronomy and Geometry, Cambridge.
G. H. DARWIN, Esq., M.A., LL.D., F.R.S., Plumian Professor of Astronomy, Cambridge.
Capt. E. H. HILLS, R.E.
FRANK MCCLEAN, Esq., M.A., LL.D., F.R.S.
Major P. A. MACMAHON, D.Sc., F.R.S.
H. F. NEWALL, Esq., M.A.
Capt. WILLIAM NOBLE.
A. A. RAMBAUT, Esq., D.Sc., F.R.S., Radcliffe Observer.
G. M. SEABROKE, Esq.
E. J. SPITTA, Esq.
W. G. THACKERAY, Esq.

MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

VOL. LXI. MARCH 8, 1901. No. 5

Dr. J. W. L. GLAISHER, F.R.S., PRESIDENT, in the Chair.

Robert William Chapman, M.A., B.C.E., Lecturer in Engineering and Physical Science in the University, Adelaide, South Australia; and

Charles J. Isaac, Head of the Upper Nautical School, Greenwich Hospital Schools, and 6 Maze Hill, Greenwich, S.E.,

were balloted for and duly elected Fellows of the Society.

The following Candidates were proposed for election as Fellows of the Society, the names of the proposers from personal knowledge being appended:—

Jnan Saran Chakravarti, M.A., Assistant Accountant-General, Rangoon, Burma (proposed by P. Doyle);

Charles Sidney Mence, Teacher of Navigation and Nautical Astronomy, 49 Watling Street, E.C. (proposed by V. L. D. Broughton);

The Rev. John Stutter, O.S.B., Acton Burnell, Shrewsbury (proposed by A. C. D. Crommelin); and

Ernest George Wainwright, B.A., Lecturer in Mathematics and Physical Science, St. John's College, Battersea, S.W. (proposed by A. E. Moore).

One hundred and two presents were announced as having been received since the last meeting, including, among others :—

Galileo, Opere, Edizio Nazionale, vol. 8, presented by the Italian Government ; Leipzig, Astronomische Gesellschaft Catalog, Zone $-2°$ bis $+1°$ (Nicolajew), presented by the Society ; F. Nansen, Scientific Results of the Norwegian North Polar Expedition, pt. vi. Astronomical Observations, arranged and reduced under the supervision of H. Geelmuyden, presented by the Editor ; Potsdam, Astrophysikalisches Observatorium, Photographische Himmelskarte, Band 2, presented by the Observatory ; H. H. Turner, Modern Astronomy, presented by the Author.

Lantern slides from photographs of the total solar eclipse of 1900 May 28, presented by Count de la Baume Pluvinel.

On the Oxford Photographic Determinations of Stellar Parallax. Reply to the Criticisms of Sir David Gill. By H. H. Turner, D.S.C., F.R.S., Savilian Professor.

In the *Annals of the Royal Observatory, Cape of Good Hope*, vol. viii. Part II., "Researches on Stellar Parallax made with the Cape Heliometer," recently published, Sir David Gill criticises adversely the observations of stellar parallax at the Oxford University Observatory in the years 1886 to 1892, saying that they "cannot be regarded as of proved value, and are certainly not reliable within limits corresponding to the probable errors assigned to them by Professor Pritchard" (Introduction, p. xv). I had nothing whatever to do with this work, which was completed and published before I succeeded Professor Pritchard as Director of the Observatory. But the reasons given by Sir David Gill for his opinion are based on the printed figures, which lead me to such diametrically opposite conclusions that I feel bound to draw attention to the matter. The main reason given for condemning the results is that the determination of scale value on the photographs is faulty. These are Sir David Gill's actual words :—

"Pritchard's method of determining the scale value would be justified if numbers of pairs of stars on the same plate were measured, and the correction for scale value was derived from the mean of all these measures instead of from only one pair. But this is precisely what Pritchard does *not* do. In his first publication on stellar parallax (Fasciculus III., *Oxford University Observations*) he measures two pairs of comparison stars for each investigation of parallax, but he derives corrections for scale value separately from the measures of the stars $a-b$ and $c-d$. It is evident that if the observations were reliable we should

have within accidental error of observation the same correction for scale value per 1000″ from the observations of both pairs; but this is far from being the case. For example we find :—

Difference from Assumed Mean.

1886.	$a-b$.	$c-d$.
June 23	$+0''\cdot885$	$-0''\cdot455$
June 24	$-0''\cdot742$	$+1''\cdot199$

"These, it is true, are extreme cases, but *throughout the series there is little evidence of systematic agreement even in the signs of the scale-value corrections*, and their average discordance is very much greater than the probable accidental error of observation which has been derived by Professor Pritchard."

Now these figures and the statement which follows them are, in my opinion, both wrong. In the first place as regards the figures. The impression given, I think, is that they represent the correction for scale value per 1000″, whereas they are quoted for $a-b$ from Table I. on p. 6, which gives the correction in 2382″; and for $c-d$ from Table XIV. on p. 40, which gives the correction in 2066″. If Sir David Gill had read the work with more care he would have seen that Professor Pritchard has rendered the figures comparable by giving in Table XIII., on pp. 38, 39, the corrections per 1000″ for $a-b$ and $c-d$ side by side; and he would also have noticed that one of the four quantities quoted by him has, by a typographical error, a wrong sign, viz. the value of $c-d$ for June 24 is $-1''\cdot199$ and not $+1''\cdot199$. (He could also have inferred this from the column immediately preceding it on p. 40; three numbers following are given with wrong sign: they are, I think, the only errors of sign in the two tables.) Thus the real figures for the correction per 1000″ are as follows :—

Difference from Assumed Mean.

1886.	$a-b$.	$c-d$.
June 23	$+0''\cdot372$	$-0''\cdot220$
June 24	$-0''\cdot312$	$-0''\cdot581$

which give a very different impression from those quoted above.

It is particularly unfortunate that this Table XIII. escaped Sir David Gill's attention, for it is immediately followed by these words of Professor Pritchard :—

"The inspection of the table suggests, I think, that the principal cause of the variations in question lies not so much in accidental or local variations of the film as in actual variations in the focal length of the mirror. *This suggestion seems to me to be borne out by the general prevalence of the same sign being attached to the variations on the same night.*"

I have italicised sentences in the quotations from Sir David Gill and from Professor Pritchard in order to bring out the fact that they are directly at issue in their views of

the same figures. And now which of them is right? The point is a most important one (at least for the value of the Oxford work), and I venture to repeat Table XIII. in a slightly modified form, arranging it in order of the mean value of the two corrections instead of in order of date as given; but the dates are added, so that anyone who has not a copy of the work can reconstruct Table XIII. in its original form if he so desires. To eliminate the effect of accidental error to some extent means of every ten numbers down the series have been taken. The year is omitted from the date for brevity's sake; for though the observations extended from 1886 May 30 to 1887 May 31, there is no risk of confusion. May 30 belongs to 1886, and all other dates in May to 1887.

TABLE XIII.

Rearranged from No. III. of the Astronomical Observations made at the University Observatory, Oxford.

Date.	Variation in Measure. $a-b$.	$c-d$.	Date.	Variation in Measure. $a-b$.	$c-d$.
	$''$	$''$		$''$	$''$
Jan. 5	−0·682	−0·592	Sept. 13	−0·246	−0·013
Jan. 12	−0·680	−0·542	Apr. 19	−0·274	+0·016
Jan. 20	−0·553	−0·509	Dec. 9	−0·199	−0·052
June 24	−0·312	−0·581	Nov. 23	−0·225	−0·025
Jan. 31	−0·492	−0·398	Sept. 11	−0·154	−0·080
Dec. 14	−0·476	−0·398	Nov. 5	−0·061	−0·148
Feb. 8	−0·371	−0·442	Apr. 25	−0·144	−0·047
Dec. 16	−0·570	−0·198	Nov. 16	−0·177	−0·004
May 13	−0·401	−0·336	June 28	−0·106	−0·046
Jan. 8	−0·424	−0·312	May 20	−0·198	+0·079
Mean ...	−0·496	−0·431	Mean ...	−0·178	−0·032
Feb. 17	−0·369	−0·302	Dec. 4	−0·170	+0·063
Dec. 24	−0·508	−0·136	Aug. 28	+0·095	−0·179
May 14	−0·372	−0·196	May 9	−0·038	−0·040
Mar. 16	−0·269	−0·256	Sept. 30	+0·102	−0·176
May 10	−0·202	−0·273	Aug. 20	−0·053	−0·019
Sept. 27	−0·183	−0·281	Dec. 2	−0·047	+0·003
May 5	−0·222	−0·227	Oct. 21	−0·046	+0·004
June 1	−0·175	−0·273	May 30	+0·135	−0·171
Sept. 18	−0·172	−0·262	Oct. 13	−0·017	−0·013
Sept. 15	−0·272	−0·161	June 15	−0·179	+0·155
Mean ...	−0·274	−0·237	Mean ...	−0·022	−0·037

Date.	Variation in Measure. a−b.	c−d.
June 16	−0″·102	−0″·315
Sept. 22	−0·122	−0·292
Sept. 17	−0·220	−0·179
May 16	−0·360	−0·031
May 18	−0·205	−0·186
Aug. 29	−0·167	−0·207
Feb. 26	−0·210	−0·150
Dec. 7	−0·196	−0·148
May 7	−0·134	−0·181
Nov. 18	−0·127	−0·155
Mean ...	−0·184	−0·184
Oct. 2	−0·003	+0·070
May 26	+0·011	+0·109
Dec. 1	+0·059	+0·063
Oct. 6	+0·029	+0·109
Mar. 12	+0·021	+0·118
June 23	+0·372	−0·220
Oct. 22	+0·094	+0·058
Feb. 25	+0·120	+0·066
Sept. 7	−0·045	+0·238
Jan. 10	+0·101	+0·092
Mean ...	+0·076	+0·070
Sept. 10	+0·200	+0·042
Jan. 25	+0·114	+0·136
May 31	+0·102	+0·150
Aug. 24	+0·191	+0·142

Date.	Variation in Measure. a−b.	c−d.
Apr. 26	−0″·048	+0″·035
Nov. 17	+0·031	−0·035
June 30	+0·295	−0·296
Aug. 30	+0·041	−0·038
Nov. 29	+0·016	−0·002
Apr. 30	+0·004	+0·011
Mar. 23	−0·093	+0·123
Apr. 29	−0·011	+0·061
Nov. 3	+0·010	+0·044
June 4	−0·126	+0·180
Mean ...	+0·012	+0·008
Mar. 27	+0·184	+0·155
Aug. 31	+0·183	+0·169
Apr. 2	+0·205	+0·170
Sept. 29	+0·236	+0·157
Sept. 20	+0·240	+0·184
July 1	+0·145	+0·316
Mean ...	+0·180	+0·162
Sept. 16	+0·326	+0·160
Feb. 5	+0·212	+0·312
June 8	+0·406	+0·223
Apr. 20	+0·223	+0·449
Aug. 26	+0·291	+0·415
Apr. 16	+0·558	+0·156
Feb. 27	+0·436	+0·303
Mean ...	+0·350	+0·288

Collecting the means of groups, we have the following correspondences :—

a−b.	c−d.	Difference.
−0″·496	−0″·431	−0″·065
−0·274	−0·237	−0·037
−0·184	−0·184	0·000
−0·178	−0·032	−0·146
−0·022	−0·037	+0·015
+0·012	+0·008	+0·004
+0·076	+0·070	+0·006
+0·180	+0·162	+0·018
+0·350	+0·288	+0·062

The general agreement is extremely good, although there are traces of a small systematic difference. It seems extraordinary that Sir David Gill should say: "Throughout the series there is little evidence of systematic agreement, even in the *signs* of the scale-value corrections." The most obvious supposition is that he looked at the figures so hastily as to make some mistake in assigning corresponding nights to one another. But is a hasty glance of this kind sufficient evidence upon which to condemn a great piece of work? There are some discrepancies in the individual nights which I felt might be due to numerical mistakes in computation. I have accordingly examined the original figures (the books being still at the observatory), and have found several such errors; but they do not materially affect the general result, and it is unnecessary to give them here. The greater part of them refer to the early observations, from 1886 May 28 to July 1. The reductions of these are mixed up with much experimental work in the determination of scale values, and in copying for the press it has, for instance, not been noticed that for the period June 23 to July 1, when a different mirror was in use, a scale value had been used for $a-b$ slightly different from that for $c-d$. When this is put right the extreme cases quoted by Sir David Gill, as well as another on June 30 (better seen in Table XIII., Table XIV. being here of wrong sign, as above remarked), disappear. But I cannot find the observations of June 28, and generally these early observations might reasonably be excluded. From 1866 August 20 the reductions are all made consistently and continuously, though there are a few errors in copying for $c-d$ from May 10–20, the removal of which would improve the agreement on May 20, not altering the other days much.

But it is not my present purpose to undertake a systematic re-examination of the whole work—merely to point out that Sir David Gill's criticisms, which refer to the printed figures, are not supported by those figures themselves.

Having set up this imaginary fault in the observations, Sir David Gill proceeds to explain it by an equally imaginary cause:—

"The obvious explanation is that in the process of development distortion of the film takes place, and this distortion is different in different position angles. As no réseau was employed, no means exist for eliminating the systematic error so produced except the crude assumption which Pritchard apparently adopted, viz. that this contraction of the film is proportional to the distance along any straight line passing through the centre of the plate, but different along different straight lines passing through the same centre. No attempt is made to test the accuracy or otherwise of such an assumption."

We have heard before of this distortion of the film. The réseau was proposed in 1887 as a means of obviating it; and in 1888 Sir David Gill included in a large scheme for measurement of the plates an elaborate determination of this distortion on

each. His observatory has now been at work for some years on the measurement of stellar photographs, and perhaps we may soon look to *him* for "an attempt to test the accuracy or otherwise of such an assumption." Till we have positive evidence of some kind I for one shall venture to question the existence of this bugbear; and one of my reasons for this temerity is precisely the examination of these measures of Pritchard (or rather of his assistants), made without any réseau and yielding such accurate results. The réseau is a great convenience in measuring, but we have possibly altogether overrated its importance for the purpose for which it was invented. Of course a photographic plate is not perfect: there are all sorts of errors of a small kind—the granulation is itself a source of error, and the curvature of the glass, and its flexure, and so on. But these are of the nature of *accidental* errors, to be eliminated by taking plenty of photographs (as Pritchard did—four on each night) and measuring them under different conditions, not of *systematic* errors to be elaborately investigated. Nor did Pritchard necessarily use the different scale values in different directions because of possible distortion of the film. He did not believe in this distortion, as appears from the paragraph quoted from his work, and as I could show further by quoting from long letters to Sir David Gill, of which copies are in this observatory. But there may be very good reasons for using different scale values in different directions, quite independent of any hypothesis about distortion of the film. I mention one or two, quite on my own responsibility, not arising out of anything I have seen in Pritchard's work.

1. If the mirror or lens with which the photographs are taken is not an accurate surface of revolution (either essentially or because of flexure), its curvature in different directions, and therefore its focal length, will vary. There are obvious reasons why mirrors should err in this way more than lenses; and it is a curious fact that plates taken with mirrors *do* show some variation in scale in different directions, *e.g.* the photographs of *Eros* taken with the 30-inch mirror at Greenwich (*Monthly Notices*, lix. p. 13). If this is a *vera causa* Pritchard's rule would be essentially correct.

2. If the plate is not strictly normal to the axis of the telescope, there would be a variation in scale in different directions. But in this case Pritchard's rule would not be quite correct. If, for instance, the twist was about the line joining *ab*, then the scale value would remain unaltered for the direction *ab*, and would be altered in the direction *cd*; but the distance from *c* to the star might be increased, while that from the star to *d* was diminished, or *vice versa.*

3. If the distances on the plate in the direction *ab* were *measured on a different day* from those in the direction *cd*, then Pritchard's rule would be essentially correct. The small variations would then depend partly on the different expansions of the plate with temperature.

Further reasons for treating the Oxford determinations of stellar parallax with scant respect are mentioned by Sir David Gill, viz. the statements of Mr. H. S. Davis in the *Annals of the New York Academy of Sciences*, vol. x. p. 160. The following are Mr. Davis's words :—

"In the formation of Table XXIII., giving the various values of the parallax of 61 *Cygni* hitherto published, I have not placed Pritchard's values in bold type because they cannot be regarded as trustworthy. They have been discarded in taking the means of the determinations for 61^1 and 61^2. I have examined the eight sets of normal equations given in the work on 61 *Cygni* (pages 17–63), and among the eight sets have not found one which is correct in every quantity. The set on page 30 first attracted my attention, and so it may be used for illustration. As given there the quantities are :—

$$\begin{aligned} -\ 1''\cdot 3140 &= +88\cdot 0000x - 6\cdot 7889 d\mu - \ 2\cdot 5442\pi \\ +\ 4''\cdot 3827 &= -\ 6\cdot 7889 \quad + 8\cdot 4762 \quad +\ 9\cdot 7965 \\ +17''\cdot 1716 &= -\ 2\cdot 5442 \quad + 9\cdot 7965 \quad + 38\cdot 7724 \end{aligned}$$

These should be

$$\begin{aligned} -\ 1''\cdot 2180 &= +88\cdot 0000x - 6\cdot 7889 d\mu - \ 0\cdot 9281\pi \\ +\ 4''\cdot 3853 &= -\ 6\cdot 7889 \quad + 8\cdot 4783 \quad +\ 9\cdot 7854 \\ +17''\cdot 1967 &= -\ 0\cdot 9281 \quad + 9\cdot 7854 \quad + 38\cdot 7849 \end{aligned}$$

The criticism applies not only to the normals for 61 *Cygni*, but for many of the other stars as well. No attempt has been made to verify all the numbers in each set of normals, nor indeed to extend the test to all sets of normals given in the book ; but it can be stated that at least one number is wrong in each of the fourteen sets given on pages 17, 23, 30, 36, 47, 52, 58, 73, 75, 87, 104, 106, 107, and 113."

These remarks of Mr. Davis (which I had not been able to find until I had written the earlier part of this paper) are quite in accordance with my own experience of the work. It certainly contains far too large a number of numerical mistakes, and I have spent too many years detecting and correcting such errors to feel any inclination to defend or condone them. If Mr. Davis insists on rejecting this work because of such errors, and of the general mistrust which their existence inevitably causes, I for one shall not attempt to question his legal right to do so. I would only remark that it is quite possible to over-estimate the importance of such errors and the effect they have on the result. They are of the nature of accidental errors, and will increase the probable error ; hence they do not give any false appearance of accuracy. And as regards the main result, it is wonderful how little this is often affected by the correction of such errors when the total number of observations is large. Those who have had experience of examining masses of observations know this well.

The example given by Mr. Davis involves corrections of about $-0''\cdot008$ to x, $-0''\cdot007$ to $d\mu$, and barely $+0''\cdot001$ to π. If this example is really representative we may consider the parallaxes as given sensibly correct; for no one attaches much importance to $0''\cdot001$ or even to $0''\cdot01$. Parallaxes quoted by Mr. Davis with approval in the table from which he excludes Pritchard's measures range from $0''\cdot20$ to $0''\cdot52$.

Description of a Floating Photographic Zenith Telescope and some Preliminary Results obtained with it. By Bryan Cookson, M.A.

The instrument which is described in this paper was constructed with a view to undertaking a determination of the constant of aberration by Küstner's adaptation of the Talcott Method. Observations for this investigation have not yet been begun, but a description of the instrument and of some preliminary results obtained with it may be of sufficient interest to justify its publication.

In the usual form of zenith telescope the level is the essential part; in the present case the level is abolished and the verticality of the axis, about which the instrument is rotated, is assumed by floating the support of the telescope in a bath of mercury.

The correctness of this assumption is shown in the paper. The principle of floatation was employed as long ago as 1825 by Captain Kater in his floating collimators (*Phil. Trans.* 1825 and 1828), but seems to have been forgotten till Dr. Chandler adopted it in 1884 and applied it with great success to an instrument of very novel design which he called the almucantar. It was shown by Dr. Chandler that the floating part of his instrument returned after disturbance to within $\frac{1}{20}$ of a second of arc of the original position; that is, it resumed its original inclination to the horizon with a higher degree of accuracy than the bubble of a sensitive level would do. A zenith telescope, then, which depends on the principle of floatation might reasonably be expected, other things being equal, to give better results than one which depends on a level. In 1891 the Georgetown College Observatory erected a floating zenith telescope (a short description of it will be found on pp. 43 to 56 of the publications of that observatory): the results obtained with it seem to have been satisfactory. This is, so far as I know, the only floating zenith telescope which has hitherto been made. Two large almucantars, however, have been recently constructed, one by Professor Sampson at the Durham Observatory (*Monthly Notices*, vol. lx. p. 572), the other by Professor Howe at the Case Observatory, Cleveland, U.S.A. (*A.J.* vol. xxi. p. 57). Results obtained with these instruments have not as yet been published.

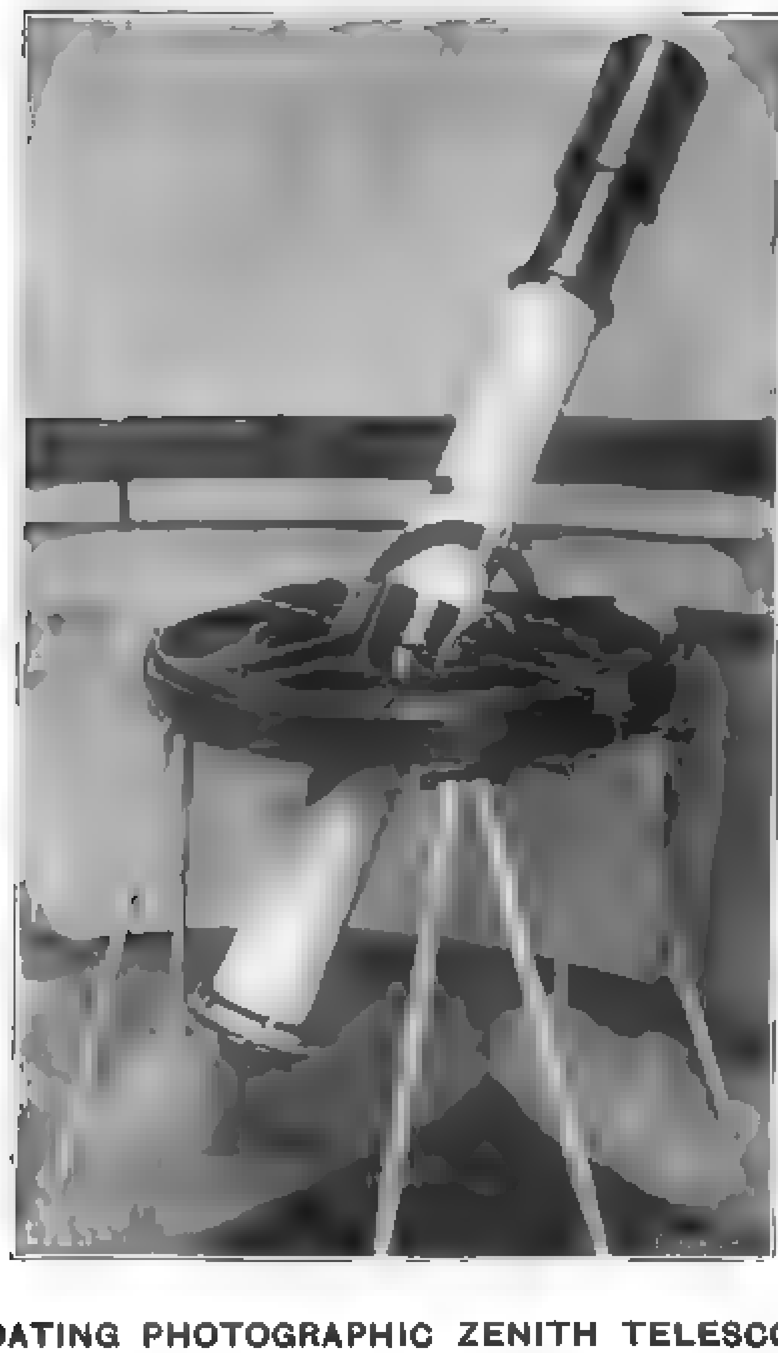
I believe there are also two instruments exactly similar to Dr. Chandler's second and larger almucantar which are in regular use in America. This completes the list of astronomical instruments actually constructed on the floatation principle.

A photographic zenith telescope of the usual form and dimensions was set up in 1895 at the Berlin Observatory, and the latitude determined with it by Dr. Marcuse, who obtained results quite as accurate as those with the visual telescope. In the case of the instrument now to be described the photographic method was adopted on account of the difficulty anticipated in the divining of some form of micrometer for use with a floating telescope, and also because, as the instrument has only to be approached in order to rotate it, there is much less chance of the heat of the observer's body affecting its condition than if he were close up to it, making bisections with the micrometer. There is also the advantage common to all photographic methods of having a permanent record of observation in the photographic plate which can be measured and reduced at the convenience of the observer. The quantity to be measured is the perpendicular distance of the marks or trails which the stars make on the sensitive plate by virtue of their diurnal motion. The results obtained by Marcuse were satisfactory in showing that the accuracy of measurement of star trails was of a high order; indeed it might be expected that a star trail on a photographic plate could be set upon at any rate as accurately as a moving star in a visual telescope, although this can be done by a skilful observer with surprising accuracy.

Description of Instrument.—It will be best first to give a general idea of the form of the instrument. There are three principal parts—the trough, the float, and the telescope. The trough and float are shallow annular basins; the float is concentric with the trough, and fits inside it with half an inch clearance all round. Mercury is poured into the trough, and the float is free to take up its position of equilibrium in the bath of mercury. The telescope passes through the centre of the annulus, and its trunnions rest in V's, which are carried by the float. The trough is fixed, but the float is free, and can be rotated in azimuth.

It was decided to adopt the annular shape for the trough and float for two reasons: first, because the rotation of the telescope about the vertical could be most easily performed by moving the float round inside the trough; and secondly, because the float could be rotated exactly through 180° by always bringing two points on it opposite two fixed points on the trough. It follows from this and the fact that the axis of rotation is vertical that the line of intersection of the plane of the meridian with the plane of the photographic plate is the same line on the plate before and after rotation.

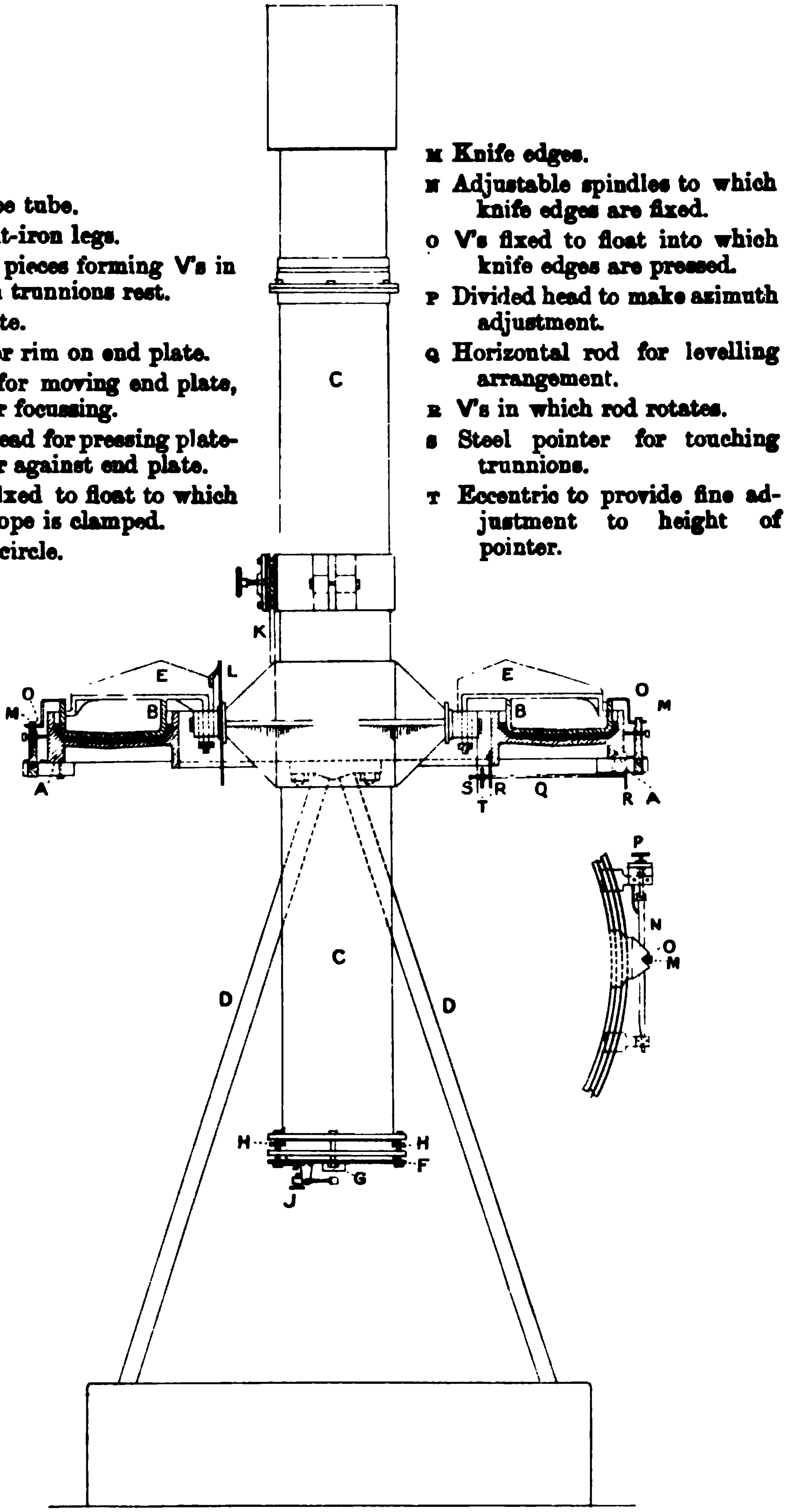
The trough, A, and float, B (Plates 8, 9), are of cast iron, and the whole of the outside of the latter is turned and polished. The out-

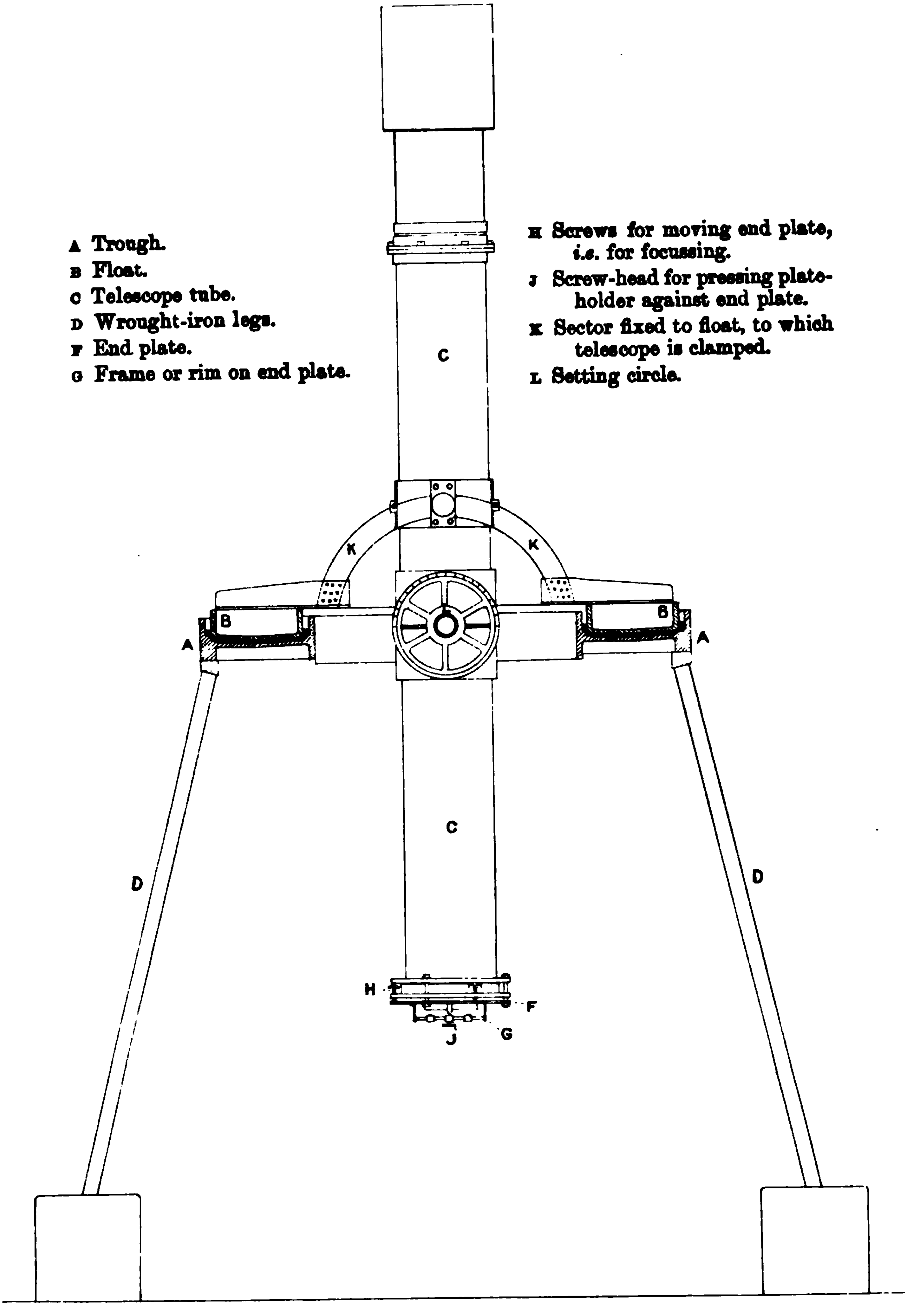


FLOATING PHOTOGRAPHIC ZENITH TELESCOPE.

BRYAN COOKSON.

A Trough.
B Float.
C Telescope tube.
D Wrought-iron legs.
E Bracket pieces forming V's in which trunnions rest.
F End plate.
G Frame or rim on end plate.
H Screws for moving end plate, *i.e.* for focussing.
J Screw-head for pressing plate-holder against end plate.
K Sector fixed to float to which telescope is clamped.
L Setting circle.
M Knife edges.
N Adjustable spindles to which knife edges are fixed.
O V's fixed to float into which knife edges are pressed.
P Divided head to make azimuth adjustment.
Q Horizontal rod for levelling arrangement.
R V's in which rod rotates.
S Steel pointer for touching trunnions.
T Eccentric to provide fine adjustment to height of pointer.




A Trough.
B Float.
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D Wrought-iron legs.
F End plate.
G Frame or rim on end plate.
H Screws for moving end plate, *i.e.* for focussing.
J Screw-head for pressing plate-holder against end plate.
K Sector fixed to float, to which telescope is clamped.
L Setting circle.
C
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G
J

side diameter of the float is 39 inches, the inside 24 inches, and there is $\frac{1}{4}$ inch of mercury between the trough and float, except at the free surface where there is $\frac{1}{2}$ inch. The float is $\frac{3}{8}$ inch thick, weighs very nearly 150 lb., and its cross-section is slightly V-shaped at the bottom to assist small bubbles of air in the mercury to escape from under it. About 142 lb. of mercury are in use, and the whole of the floating parts weighs 350 lb. To prevent the float from knocking against the trough whilst being rotated, a circumscribing polygon of wire is attached to the trough and stretched round the float, so as just to clear it when it is in position. This wire acts as a spring, so that the float suffers no jarring knocks against the sides of the trough.

The trough is supported by three pairs of wrought-iron rods, D, $1\frac{1}{4}$ inch in diameter, each pair forming an inverted V. The plane of these V's slopes outwards from the trough to give clearance room for the telescope when it is being rotated at considerable zenith distances, and also to increase the stability of the support. The height of the bottom of the trough above the floor is 4 feet 6 inches, and the maximum zenith distance at which the telescope can be rotated is 45°.

The telescope is carried in the centre of the annular float by means of two overhanging cast-iron bracket pieces, E E, forming the V's in which the telescope trunnions rest. The tube C is brass, $\frac{1}{8}$ inch thick and $7\frac{1}{4}$ inches internal diameter. The upper end carries the object glass attached to a flange, and at the lower end there is a circular end plate, F, perforated by a rectangular aperture which is slightly smaller than the sensitive plate, and which admits the light from the object glass to it. This aperture is surrounded by a raised rim or frame, G, $\frac{1}{2}$ inch deep, against which the plate is pressed during exposure. The focussing is effected by means of three screws, H, which move the end plate relatively to the telescope tube: their pitch is 1 mm., and they have divided loads so that the focus can be set to 0·01 mm. These screws also regulate the tilt of the photographic plate to the optic axis of the lens; and once the focus found and this adjustment made, they are clamped.

The instrument is used for photographing the trails of stars across the meridian; the point on the trail corresponding to the moment of meridian passage is marked by a gap or break in the trails. This gap is the shadow cast by a thin copper wire, about 0·1 mm. in diameter, which is attached to the above-mentioned frame so as to lie just level with the top of it. Means are provided for making the necessary adjustment to bring this wire into the meridian. There are also two similar parallel side wires, each distant 9 mm., or 75 equatorial seconds from the central wire.

There are six plate holders made of brass, and they fit like a lid on to the frame of the plate aperture. They are held in this position by a simple arrangement, and after the dark slide is drawn are pressed home by simply turning a screw head, J, so

that the sensitive plate rests against the frame, G, on the end plate; the frame then lifts the plate off the ledge in the holder, and springs at the back of it press the plate at three points against three small steel points let into the frame on the end plate. In this way every plate is exposed at exactly the same distance from the object glass. The marks on the gelatine made by the steel points are useful in showing the position in which the plate was exposed.

A great deal of trouble has been found in devising an efficient clamp to hold the telescope relatively to the float, and a new one has recently been added. The original clamp, with a slow-motion screw, acted on one of the trunnions, and its arm was held by one of the bracket pieces which carry the telescope. The origin of the trouble was eventually proved to be in the bracket piece itself: it was not sufficiently rigid, acting through the short arm of the clamp, to make the telescope exactly respond to the rapid changes of direction of motion which the float undergoes when executing its metacentric oscillations, and this of course entirely vitiated all results for the latitude. In the new clamp the telescope tube itself is clamped to a circular sector, K, which is firmly fixed to the float: this arrangement has been found to perform most satisfactorily. The old clamp with its slow-motion screw can be used for setting to the required zenith distance.

The brass finding circle, L, 9 inches in diameter, is a very simple and inexpensive one: it is divided to half a degree and the setting is made to $0^\circ{\cdot}1$ simply by a pointing index, which is quite sufficient for all practical purposes. The divisions are cut on a strip of celluloid let into the brass circle.

A few words must be said concerning the object glass. A good deal of time and trouble was taken over the choice of a lens, and it was eventually decided, after making some experiments, that a Cooke lens, Series I. c (Taylor's patent), of $6\frac{1}{2}$ inches clear aperture and 65·4 inches focal length, would be most suitable. This lens has a flat field of 14° diameter, but owing to the distance between the first and third component lenses not more than half its field is illuminated with full aperture, though for its present purpose this is no disadvantage, as the maximum angular distance that is covered by the plates is $3^\circ{\cdot}2$. The performance of this lens is satisfactory in the highest degree: the star trails are wonderfully sharp and distinct. Though the curvature of the middle lens—a negative flint—is considerable, the change of focal length with temperature is small, because the part due to altered refractive index is compensated by that caused by change in the separation of the component lenses. I have calculated the change due to a rise of temperature, and find that the sensitive plate, which is connected to the lens by means of a brass telescope tube, will be removed just over 0·01 inch from the focus for a rise of 10° C. Observations made to determine the focus are in complete accordance with Lord Rayleigh's

formula,* and show that this is just the limiting displacement possible without impairing definition.

The three instrumental adjustments are: 1. Azimuth. 2. Level. 3. Collimation.

1. When the instrument is being used for observations the float must be held in azimuth, so that the axis of the telescope shall be in the meridian, but in such a way that there shall be no force to restrain its free oscillatory motion in the plane of the meridian. Two points therefore at the ends of an east and west diameter are held in the following manner: Knife edges, MM, are fitted to horizontal spindles, N, which are held by the trough, and are pressed by weak springs into two V's, OO, fixed to the float. The knife edges can be pulled back out of the V's, and their positions are adjustable by means of screws with divided heads, P, so as to bring them into the correct azimuth. In this way the only line in the float which is held is the line joining these V's, and it is so arranged that this line lies in the surface of the mercury. There can thus be no force to restrain motion of the telescope in the meridian, and the frictional force of the knife edges in the V's is too small to affect the inclination of the horizontal axis of the telescope appreciably. To change the azimuth by $0^s.5$, each adjusting screw must be turned through one division of its divided head.

2. It did not seem advisable to employ the usual striding level to test the inclination of the horizontal axis, because the application of it would change the inclination of the floating instrument. The limit assigned to the level error is $\pm 1^s$, which corresponds to 0·03 mm. at an arm equal to the distance between the trunnions, viz. 20 inches, and no very elaborate arrangement is therefore required. The method adopted is to bring first one and then the other trunnion over a fixed arrangement for touching them, and thereby finding when they are at the same height over it. It consists simply of a horizontal rod, Q, which turns in V's, RR, fixed to the trough. Through the end of the rod, and perpendicular to its length, runs a stiff steel wire, S, and by rotating the rod with the fingers it can be felt with great nicety when the point of the wire just touches the trunnion. By mounting the rod eccentrically in a pulley-wheel which turns in the V, and moving the rod in this eccentric, the necessary fine adjustment is provided. The diameters of the trunnions do not differ by 0·01 mm.; and as the fingers can feel a difference of 0·01 mm. in the height of the trunnion over the touching point, it is clear that this arrangement enables the adjustment to be made with the necessary accuracy. A sliding weight is attached to one of the bracket pieces on the float, and is moved till the pointer passes both trunnions with the same ease.

3. To correct for collimation error, the frame carrying the three transit wires can be moved by loosening the screws which attach it to the frame on the end plate.

* *Phil. Mag.* Series V. vol. xx. p. 355.

With the exception of the object glass and the trough and float, the instrument was made by the Cambridge Scientific Instrument Company, and I wish to express my deep sense of gratitude to Mr. Horace Darwin for all the care he has devoted to its construction, and for the many ingenious devices which have so largely contributed to the success of the instrument.

My thanks are due to Messrs. Cooke and Sons for much valuable information, and for the loan of a lens with which to make experiments; also to Mr. Norman Cookson and the Hon. C. A. Parsons for the casting and turning of the trough and float.

The instrument is mounted in a dome at the top of the main building of the Cambridge University Observatory. This dome, and the instrument it contained, had long been out of use. Sir Robert Ball had the old telescope removed and the dome put into thorough working order, and offered me the use of it. I wish to express my best thanks to him for this and for many other kindnesses.

The diameter of the dome is 15 feet, and it can be easily pushed round by hand. The aperture of the dome is opened by three independent shutters which are pulled aside by cords, and the exposures on the stars are made by opening the appropriate shutter at the proper moment. Windows are provided for efficient ventilation of the dome. The mean difference between the temperature of the outside and of the inside air is found to be $1^{\circ}\cdot5$ C.

The Measuring Micrometer.—To determine the linear distance between the trails on the plate, one of Zeiss's Standard "Comparators" is used: with this instrument distances up to 100 mm. can be measured. A division on its micrometer head represents 0·001 mm., which corresponds to $0''\cdot12$ on the photographic plate; consequently the last or estimated figure in a reading is the equivalent of $0''\cdot01$. In the microscope for viewing the trails there are four horizontal and two close vertical wires, and the plate is moved by a slow-motion screw till the trail bisects the space between the vertical wires. This is done at eight different points on the trail, four on each side of the meridian break at equal distances from it. The horizontal wires, corresponding to the vertical wires in a visual telescope, are used to indicate these points. With the magnifying power which is always used, viz. 24, the distances of the eight points from the meridian break are $\pm 1^{s}\cdot4$, $\pm 2^{s}\cdot7$, $\pm 4^{s}\cdot1$, $\pm 5^{s}\cdot5$.

This instrument belongs to Mr. Newall, who very kindly allowed me to use it, and to have the system of wires described above put into the eyepiece. I wish to sincerely thank him for this, and also for the encouragement and advice he has always been ready to give.

In measuring, the eight settings on a trail are all made before moving to the next star. Each point is set upon twice, though lately through pressure of time the bisection has been made only

once. Preliminary experiments show that there is no systematic error depending on the direction in which the trail is brought between the vertical wires, or depending on the direction in which the plate is measured.

The division errors of the silver scale have been fully investigated by Mr. Newall, who has determined the error of every division and constructed a table of them. The error of run was found to be negligible, and the errors both periodic and progressive of the micrometer screw over the part of it in use only amount to one or two estimated places on the screw head. The only correction that is applied to the micrometer readings is therefore that for error of division. The correction for temperature, arising from the difference of expansion of the glass plate and the scale, amounts to one part in 100,000 per degree centigrade, which corresponds to $0''\cdot01$ in an arc of $21'$. Excepting in the most careful measurements, no account is taken of this.

Plates and Development.—The plates in use are Ilford Empress and Ilford Special Rapid, and all those intended for measurement are on patent plate glass. The developer has always been Metol. The Special Rapid plates are twice as fast as the Empress, and from exposures on the *Pleiades* made within a few minutes of one another, it was found that measurable trails were obtained of stars of magnitude 7·4 on Pickering's scale with the faster plate, as compared with those of magnitude 6·9 with the slower. Trails of zenith stars of magnitude 7·8 are quite easily measured on the Special Rapid plates; the grain of these plates has caused no inconvenience in the measurement.

The size of the plates is 5×2 inches.

Adjustments.—The errors of collimation and azimuth can be determined either visually or photographically, after the axis of the trunnions has been levelled in the way described above. For visual observations a negative eyepiece is fitted to the frame, G, on the end plate, and transits of suitable stars over the central wire are observed. The collimation error is found from the times of transit of two stars, culminating within a degree of the zenith, one star having been observed with the circle west, the other circle east. With the collimation error thus determined the azimuth error may be found by observing the transit of a polar star. The photographic method is, however, the easier of the two, and gives much better results. The instrument in this case is practically used as a photographic transit circle. The procedure is very similar, excepting that the collimation error of one of the side wires is determined from one star independently of the star's right ascension, the clock error and the azimuth error. Breaks in the trails are made at noted times by putting a cap before the object glass, and the distances of these breaks from any of the three wires are measured at the micrometer.

As it is important to know the limits within which the errors

must be kept, in order that their effect on the latitude deduced from a Talcott pair of stars may not amount to $0''\cdot01$, the following expression for the correction due to errors a, b, c of azimuth, level, and collimation respectively was found:—

$$\delta\phi = D\,(a^2\cos^2\phi + b^2\sin^2\phi + c^2) + Abc + Bca + Cab + \frac{\sin 2\phi}{2}(b^2 - a^2)$$

where

$$D = \tfrac{1}{2}\,\frac{\sin 2\phi}{\cos\delta_s\cos\delta_n} \qquad B = \sin 2\phi\,\frac{\sin z}{\cos\delta_s\cos\delta_n}$$

$$A = \sin 2\phi\,\frac{\cos z}{\cos\delta_s\cos\delta_n} \qquad C = \sin 2\phi\,\frac{\sin z\cos z}{\cos\delta_s\cos\delta_n}$$

and δ_s δ_n denote the declinations of the south and north stars respectively, and z is their mean zenith distance. It will be found from this formula that $\delta\phi$ will not amount to $0''\cdot01$ if a, b, c are kept within the limits $\pm 1^s$. These limits are smaller than those usually assigned, but the reason of this is that the part of $\delta\phi$ depending on the products of the errors is generally neglected.

An attempt was made to find the level error by observations of stars at zenith distances, varying from 36° N. to 52° S.; the error of the chronometer was otherwise known. The resulting error was $-0^s\cdot5$, circle west: this shows that the method adopted for levelling the axis of the trunnions performs satisfactorily.

No appreciable difference can be found between the azimuth error for circle west and that for circle east. At present it amounts to $+0^s\cdot45$.

The errors of collimation at the ends of the central wire are $-0^s\cdot46$ and $-0^s\cdot05$ circle west. The wire is therefore inclined at an angle of $0^\circ\cdot03$ to the meridian, the effect of which is quite inappreciable. The side wires are distant 75·0 equatorial seconds from the middle wire, and they do not deviate by more than $0^s\cdot05$ from parallelism to it. No correction has therefore to be applied for collimation error of any of the three wires.

Scale Value.—Though the accurate and definitive scale value is not required in the present paper, yet it may be worth while to present the result of measurements to give an idea of the degree of accuracy attained in the measurement of trails, and to show that the optical distortion of the lens is at any rate small up to the 1½° from the centre of the field. This is a point, however, which requires further careful investigation. The scale values derived from seven pairs of stars in the *Pleiades* are given in full in the table below. The positions of the stars were taken from Elkin's Memoir, *Yale Observations*, vol. i. Part I. p. 87, and ten measurements have been made from the star h and not η (*Alcyone*), as is usually done, because it was anticipated that the closeness of the trails of η and b (*Electra*) would interfere with measurements of η. The focussing screws have not been

touched or the telescope interfered with in any way during the interval in which these photographs have been taken. The values deduced from them are therefore comparable *inter se.*

Date.	$h-28$. mm. 20·7.	$h-34$. mm. 12·2.	$h-d$. mm. 5·6.	$c-h$. mm. 6·5.	$e-h$. mm. 9·3.	$k-h$. mm. 11·9.	$m-h$. mm. 20·1.	Daily Mean.	Temp. Telescope Tube. C.	Position of Circle.
Nov. 27	124″·627	″·599	″·531	″·725	″·614	″·636	″·606	″·620	+6°·7	E.
Dec. 7	·571	·632	·588	·643	·628	·647	·638	·621	6·4	W.
13	·594	·605	·606	·586	·598	·622	·633	·606	7·2	W.
14	·633	·629	·689	·477	·576	·582	·605	·599	9·2	W.
16	·638	·624	·642	·579	·628	·580	·582	·610	6·1	E.
Jan. 14	·589	...	·589	·585	·646	·648	·617	·612	3·3	E.
18	·619	...	·622	·618	·623	...	...	·621	5·0	W.
Mean	124″·610	·618	·610	·602	·616	·619	·614	124″·612		
Jan. 29	·581	·614	·687	·655	·641	·662	·631	·639	3·8	W.
31	·619	...	·650	·579	·544	·583	·573	·591	3·6	W.
Feb. 1	·621	·646	·601	·464	·560	·542	·569	·572	4·0	E.
Mean	124″·607	·630	·646	·566	·582	·596	·591	124″·601		

Under the names of the stars the approximate distance in millimetres is given; the angular distances in minutes of arc may be roughly found by multiplying by 2. These values have been corrected for geometrical distortion, due to the fact that the photograph is a plane projection of the celestial sphere; and to see if there was any marked optical distortion, the last three plates were exposed with their centres 1° from the star h. From the first seven plates the probable error of a single determination comes out as $\pm 0''\cdot 0256$; that of the mean of seven is therefore $\pm 0''\cdot 0096$, and of three $\pm 0''\cdot 0148$, so that the two means for each pair agree within the limits of their probable errors. An attempt was also made to find the distortion by measurements of some other stars whose positions were well known. Their declinations were taken from Newcomb's *Catalogue of Fundamental Stars*, and the following scale values were derived :—

Stars in Taurus. Z.D. 36°·2 S.				Stars in Perseus. Z.D. 3°·5 S.				Stars in Auriga.			
$a-80$	25·7	124″·576	4	$\lambda-\mu$	55·6	124″·633	4	$\epsilon-\eta$	74·4	124″·613	4
$\delta-a$	28·9	·637	4	$\lambda-c$	76·1	·629	4	$\epsilon-\zeta$	79·3	·612	3
$68-a$	40·2	·620	4	$c-\mu$	20·5	·610	4	$\zeta-\eta$	4·9	·420	3
$a-\rho$	48·4	·602	4								

After the names of the stars the approximate distance between the trails is given in millimetres, and after the scale value the

number of plates taken. It will be seen that very considerable arcs have been measured—the largest is 2° 45′—and if there were any distortion its effect would be greatest on these large distances. I tried to deduce from all these results by least squares an expression of the form bs^2+cs^3 to represent the distortion, but the coefficients b and c came out smaller than their probable errors. No explanation has at present suggested itself for the abnormally small value 124″·420 derived from the standard stars ξ and η *Aurigæ*. It may, however, be safely concluded that the optical distortion of the lens over the field at present in use is very small, and a considerable series of very careful measurements would be required to show it.

For the present it will be sufficient to take as the scale value that derived from the *Pleiades* stars, namely 124″·610 ±0″·0034.

Accuracy of Measurement.—The probable error of a single bisection of a star trail has been determined for three separate cases:

1. Star on meridian, float fixed so as to prevent oscillations.
2. Star on meridian, but float not fixed.
3. Star on one of the side wires and float not fixed.

In the first two cases the trail is practically parallel to the vertical wires in the microscope, but in the last the curvature of the star's path is very marked, and it was thought that this might interfere with accurate setting. Corrections having been applied for curvature of path, the probable errors of a single bisection are as follows:—

	Probable Error.	Number of Trails.	Zenith Distance.
1. Star on meridian, float fixed	″ ±0·17	34	° 28·5
2. Star on meridian, float not fixed	±0·17	37	28·5
3. Star on wire 75ˢ from meridian, float not fixed	±0·14	22	0·5

The small difference between these probable errors may be referred to the greater refraction irregularities that naturally occur in the trails of stars of greater zenith distance, and the accuracy of setting may be taken as equal in all three cases.

Now it often happens that there are perceptible traces of oscillatory motion of the float to be seen in the trail when viewed with the measuring microscope, and though a wind screen has been erected round the instrument, it seems almost impossible to entirely prevent minute oscillations from arising. The existence of undulations with an amplitude of about 0″·25 on the plate makes the trail apparently easier to set upon, but it was feared that the result might not be reliable. The equality of the probable errors in the three cases above proves, however, that neither the existence of minute undulations of the trail, nor the curvature of the star's path, nor both combined have any deteriorating effect on the accuracy of setting on a star trail.

But the accuracy of setting is far from being a true indication of the accuracy to be expected in making measurements of the same distance at different times. The probable errors, therefore, of the distances measured for scale value have been determined; for this purpose the distances have been divided into three groups, and the error found for each. The sum $[vv]$ is formed for each distance, and the probable error for the group found by the usual formula

$$p.e. = 0{\cdot}67\sqrt{\frac{\Sigma[vv]}{m-n}}$$

m being the total number of measures, n the number of separate means. The probable errors thus derived from all the stars observed for scale value are :—

Distance. mm.	Distance. arc.	Probable Error of One measured distance.
		$''$
0–15	0′–31′	± 0·218
15–30	31′–62′	± 0·358
30–80	62′–166′	± 0·503

These results are deduced from plates exposed when the float was fixed, and are therefore independent of the fact that the instrument is floating; it might, however, be imagined that if the float were free the inclination of the telescope to the horizon would be changed between the transits of the stars by a disturbance of the instrument caused by the wind. The corresponding probable errors for the case of the free float have therefore been determined in the same way.

Distance. mm.	Probable Error. $''$
0–15	± 0·206
30–65	± 0·486

There are not sufficient measurements to give a reliable error for the distances 15–30 mm. The agreement of the values for the two cases of a fixed and a free float shows that the fact that the instrument is floating does not interfere with the accuracy of measurement. This is a satisfactory indication of the remarkable stability of floatation of the instrument.

Distortion of Film.—In connection with the accuracy of measurement some experiments were made to see if any appreciable part of the errors of measurement were likely to arise from this source. Six contact photographs of a glass scale were taken, and after having been treated in various ways were measured together with the scale and compared with it. The plates were developed in Metol for periods varying from two to eleven minutes, and after having been fixed were washed in running water. The total length of the scale was 100 mm., and the

maximum difference in the length of the photograph and of the scale amounted to 0·0071 mm.; a difference in a length of 5 mm. amounting to 0·0029 mm. was found in one instance. The mean differences for lengths of 5 and 15 mm. for the six plates measured are given, together with details of treatment of plates.

Plate.	Mean Diff. expressed in 5 mm.	Photograph and Scale, 0·0001 mm. 15 mm.	Developed.	Washed.	Dried.
			m	h	
D. 3.	9·3	17·2	3	6	slowly
D. 6.	6·5	7·5	2	13	very quickly (2^h)
D. 7.	6·6	10·4	2	13	6 hours
D. 8.	9·1	20·7	2	5	slowly
D. 9.	7·8	11·7	4	2	slowly
D. 10.	8·2	9·9	11	2	slowly
Mean	7·9	12·9			

The distortion of the gelatine film does not appear from these measurements to depend on the treatment of the plate within the range of treatment here considered, and is more likely to depend on the evenness and regularity with which the emulsion is applied to the plate.

Oscillations and Stability of the Float.—The oscillations of the float are of two kinds: one is connected with the wave motion of the mercury in the trough, and the other is simply the metacentric oscillations of a floating body. It is from these last that a measure of the stability of the float can be derived, but in the practical working of the instrument they are of no importance compared with the first. Both kinds can be very conveniently studied photographically.

The photograph which is here reproduced was obtained by suspending a weight from the float and suddenly lifting it. The effect of this is to set up the wave motion in the mercury which the figure shows. Measurement of this and other negatives, showing oscillatory motion, has proved that the period—viz. $9^s{\cdot}40$ —is constant for all amplitudes. It is of some interest to compare this period with that for the free-wave motion in an annular trough of the same dimensions as the present one. In a paper to be published elsewhere I have done this, and proved that the longest period is $1^s{\cdot}6$ when there is one nodal diameter. The ratio of two successive amplitudes on the same side of the position of equilibrium is constant, and equal to 0·76, and it was found

that no trace of any disturbance producing an initial amplitude of 3·5 mm. could be seen after 206 seconds. Representing, then, the motion by the usual equation for damped oscillations, namely,

$$\frac{d^2x}{dt^2}+2a\frac{dx}{dt}+bx=c$$

these data are sufficient to show that an initial disturbance of amplitude x mm. on the photographic plate will have no appreciable effect on the trail after τ seconds, where

$$\tau=169+30\log_e x.$$

The rotation of the instrument between the two stars of a Talcott latitude pair sets up oscillations with an amplitude of about 0·25 mm., and takes 20^s to perform. In this case τ is therefore 127 seconds, and hence the right ascensions of the two stars must differ by two and a half minutes if the trails are to show no undulations. But as the rate at which the oscillations are damped is known, there seems to be no reason why undulatory trails should not be used for even the most careful measurements, for it is quite as easy to set on the crests and hollows of the waves of such a trail as on a perfectly steady one. This, however, has only been done in a few cases, and no definite conclusion can yet be stated.

To find the period of the other kind of oscillations—viz. the metacentric—it is only necessary to know the metacentric height, MG, and the radius of gyration, K, of the floating part of the instrument. In the present case MG is 10·9 feet, and K 1·8 foot. The formula

$$\tau=2\pi K\sqrt{\frac{1}{g\,.\,MG}}$$

therefore gives $0^s{\cdot}6$ for the period of the metacentric oscillations. In the figure above these oscillations show themselves in the small dots which can be seen in the first upward stroke; and, by counting them, it is found that their period is $0^s{\cdot}6$, showing satisfactory agreement with theory. Direct visual observations give the same result.

The moment required to produce a tilt θ of the float is $g\rho Ak^2\theta$, where ρ is the density of the fluid, A the area of the plane of floatation, and k its radius of gyration. (The distance between the centres of gravity of the floating body and of the displaced fluid is neglected.) It follows that a moment of a pound-foot will produce a tilt of 52″, which corresponds to a movement of the outside of the float through 0·005 inch; in other units a tilt of 1″ is produced by a moment of 260,700 centimetre degrees. Now the forces which prevent the float from returning to exactly its old position after disturbance most probably arise from differences in the surface tension of the mercury before and after disturbance. The tension of the surface of pure mercury and air is

500 degrees per linear centimetre, and it seems hardly likely that the tension of more than 10 centimetres of mercury in contact with the float could be changed by the disturbance, or even by rotation to the extent of 100 degrees per centimetre. It follows from this that the float may be expected to return to within $0''\cdot10$ of its old position; if merely shaken, to within a few hundredths of a second; and observation proves that this is really the case.

It was for directly investigating this point that three transit wires were mounted instead of only one. Their distances are such that a star in the zenith takes just four minutes to cross all three; and one method of observing is to allow two stars, which differ in right ascension by from four to eight minutes, and in declination by a few minutes of arc, to register their trails over both the side wires. The instrument is not touched during the transit of the first star, but is shaken or rotated through 360° between the transits of the second star over the two side wires. The trail of the first star serves as a reference line from which to measure the distance of the second trail at the points where it crosses the wires. We can thus directly discover whether any change of inclination of the telescope has been caused by the disturbance. This has been done with the following results.

Three plates were exposed, on which appeared the trails of six stars, whose declinations were all within 30′ of one another. Between the transits of three of them over the side wires the float or telescope was pushed by hand, but for the other three the instrument was not touched. The only reduction of the measurements that is necessary is to apply to both undisturbed and disturbed trails the mean difference between the readings at the two wires for the undisturbed trails in order to correct for the shift of the plate relatively to the scale of the micrometer in moving from one wire to the other. If there were no errors of measurement the shift of the plate, as shown by the three undisturbed trails, should be the same. The actual figures are as follows:—

	Undisturbed.		Disturbed.	
	$0^{mm}\cdot001$	Arc.	$0^{mm}\cdot001$	Arc.
		″		″
Jan. 29	+ 3	+0·04	−19	−0·24
	−24	−0·30	+22	+0·27
	+22	+0·27	− 4	−0·05
Jan. 31	+ 8	+0·10	−16	−0·20
	+ 8	+0·10	+ 6	+0·07
	−17	−0·21	0	0·00
Feb. 1	+21	+0·26	+12	+0·15
	− 4	−0·05	+ 5	+0·06
	−16	−0·20	−29	−0·36

The sums of the squares of these residuals are almost identical, and this shows that the accuracy of floatation is, at any rate, as great as that of the measurement of the trails.

To test the effect of not merely shaking the float but of rotating it through 360°, four other pairs of stars in about declination +58° were chosen and observed in the same way, but for the addition of the complete rotation. The figures given below are the excess of the distance between the trails before rotation over that after rotation; the approximate distance is also added.

	I.	II.	III.	IV.
	20′·1	9′·4	27′·9	7′·6
Jan. 29	−0″·21			
31	−0″·51			
Feb. 2		+0″·20	+0″·80	−0″·76
3		−0″·15	+0″·35	+0″·19

The rotation of the float and telescope was purposely not made with any particular care, so that the performance of the instrument is very severely tested. Now the mean of these eight differences, regardless of sign, is 0″·40, and the mean formed in exactly the same way for the three undisturbed trails above is 0″·30, the total distance for these last being only one-seventh of the total distance of the trails in the present four pairs of stars. This leads to the satisfactory conclusion that even a complete revolution of float and telescope does not appreciably disturb the inclination of the telescope to the vertical. With regard to the accuracy of measurement here indicated, it is interesting to note that the probable errors found for a single bisection of a trail or of a measured distance compare very favourably with those found by other observers with different but comparable instrumental means.

To test the stability of floatation yet further a method has been devised to investigate the effect of a half revolution of the float—a rotation through 180°; and this case is really of the most interest because it is that which actually occurs in observations of the latitude. The method is as follows: A star culminating within 1° 20′ of the zenith is allowed to register its trail over the first side wire, the telescope being clamped and pointed exactly to the zenith; the float and telescope are then rotated through 180°, so that the wire which was first before rotation is now the last. The time required for a zenith star to cross the wires being four minutes, there is plenty of time to effect the rotation and for the telescope to come to rest before the star again crosses the wire. This it does, but of course in the opposite direction and on the opposite side of the zenith on the plate. The zenith then is the point midway between the two trails made by the star; and if several stars are allowed to register their trails the zenith points derived from them should agree within the limits of errors of measurement. At the same time if the declination of the star is known, half the distance between the trails of the star added to or subtracted from, as the case

may be, the apparent declination will give the latitude. The discussion of this is reserved for another section.

The following is an example, chosen at hazard, of the method employed :—

	Star.	Corrected Reading. mm.	Zenith Point.
L. 7, Feb. 11	2*a*	60·6393	41·8202
	b	23·0010	
	3*a*	26·3290	41·8237
	b	57·3184	
	5*a*	49·7550	41·8194
	b	33·8837	
	1*a*	33·4036	39·5275
	b	45·6513	
	4*a*	33·2343	39·5305
	b	45·8267	

No corrections are necessary except those for errors of the micrometer. The first three stars registered their trails over the wire called III, the last two over wire I; and the maximum difference in right ascension of the stars on the same wire is 16·2 minutes. The thermometers both inside and outside the dome and on the instrument showed, as is usual, no change of temperature during this interval. The two stars 2 and 3, having very nearly the same right ascension, form a pair, and the zenith points deduced from them would be the same were there no errors of measurement. Twenty-four determinations of the zenith point from two or more stars, similar to the two examples given here, have been made; but the differences of the zenith points determined by the two stars of the pair 2 and 3 above and another such pair, the probable error of the determination of a zenith point arising from error of measurement alone, is found to be $\pm 0''\cdot223$; and from the stars not forming pairs, such as 1 and 4 above, the probable error due to error of material is not sufficient to make it possible to deduce the probable errors of the determination of the zenith point arising from accidental errors of measurement and from the error of floatation. All that can be stated at present is that the mean difference in the reading for the zenith point is $0''\cdot30$ for a pair of stars, and $0''\cdot37$ for stars not forming pairs: the former figure rests on ten determinations, and arises from error of measurement alone; the latter is the mean of twenty, and is due to the errors of measurement and of floatation combined.

Latitude.—Owing to continued bad weather it has not been possible to secure a series of observations of Talcott stars, but the measurements of trails of zenith stars taken to test the stability of the float have been reduced and the latitude derived from them. This method of finding the latitude consists simply in the observation of the zenith distance of single stars. A star registers

its trail across a wire two minutes before its meridian passage: the float and telescope which is pointed to the zenith are then rotated through 180° in azimuth, and the star crosses the same wire as before two minutes after meridian passage; but the two trails made by the star are on opposite sides of and at equal distances from the projection of the zenith on the plate. From half the measured distance between the trails the meridional zenith distance of the star is found by applying the following corrections:—

1. Correction for curvature of star's path or reduction of the meridian given by the formula

$$c=\frac{15^2}{2}\sin 1''\tan\delta\, C^2$$

where C is the collimation constant expressed in equatorial seconds. This correction is a constant for each star, and is always to be added to the declination.

2. Correction for projection of the celestial sphere on to the photographic plate. The sign of this correction is the same as that of the star's zenith distance, and its magnitude is found from the expression

$$1''\cdot 52\, x^3\, 10^{-5}$$

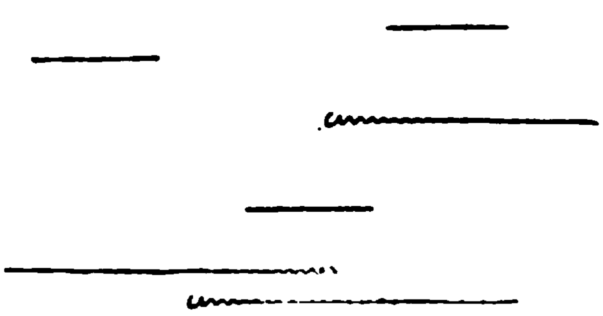
where x is the distance in millimetres from the centre of the plate. When the distance x' is not measured along a line passing through the centre of the plate, but along a line distant y millimetres from the centre, the correction is

$$\delta x'=1''\cdot 52\, x'(x'^2+y^2)10^{-5}$$

This correction is most easily applied by reading off its value from a large scale chart showing the values of $\delta x'$ for a given value of x', y being an instrumental constant.

3. The last correction is that for refraction. This is small, as only stars culminating within $1\frac{1}{2}$° of the zenith can be used; but it undergoes small variations with the meteorological conditions unless the zenith distance does not exceed 20.

Of these three corrections the first two are constants for a given star, and are to be applied once and for all to its mean declination. The only day corrections are the refraction and the reduction to date. The latter has been carried out by means of Finlay's Star Tables.



The appearance of a latitude plate is shown above; the oscillations are caused by the rotation of the float and telescope.

Twenty-six stars were chosen, so that the sums of the north and of the south zenith distances were very nearly equal. The mean latitude from all the stars would in this way be made very nearly independent of the scale value, but cloudy weather unfortunately prevented these observations from being completely carried out on even one night. The following results, however, are given in order to show what may be expected from this method of observing with the instrument.

In the following table the declinations are given of those stars of which observations have been secured. In the second column N. denotes Newcomb's *Catalogue of Fundamental Stars*, 1900; P. the Poulkova Catalogue of 1855, published in vol. viii. of the *Poulkova Observations*; and A.G.C. the Harvard Zones of the *Astronomische Gesellschaft* Catalog. The declinations of the Poulkova Catalogue have been reduced to Newcomb's system by applying the corrections given in his Catalogue, p. 234, and the Harvard declinations by means of those given in the introduction of the Catalogue of that observatory.

Group and Number.	Catalogue.	Approx. R.A. 1901. h m	Declination 1901. ° ′ ″	Proper Motion 0″·001.	Approx. z. d.
L. 1. 1	N. 182	2 47·2	52 21 26·95	− 3	− 8·9
2	A.G.C. 1353	53·7	51 57 30·83		+15·0
3	N. 190	57·6	53 7 8·24	− 4	−54·6
4	A.G.C. 1388	3 0·9	51 49 56·74		+22·6
5	A.G.C. 1405	4·5	51 47 20·28		+25·2
L. 2. 1	P. 694	4 32·0	52 52 55·96	− 19	−40·3
2	P. 693	32·0	53 16 41·48	− 91	−64·1
3	A.G.C. 1932	37·1	52 9 12·56		+ 3·4
4	A.G.C. 1996	45·2	52 40 27·41		−27·9
5	P. 770	58·8	51 27 59·86	−166	+44·7
6	A.G.C. 2116	5 6·7	53 5 47·12		−53·1
x	P. 739	4 49·3	53 35 38·05	+ 12	−83·0
L. 5	N. 520	8 1·0	51 47 32·17	− 3	+25·4
L. 6	N. 546	8 32·0	53 3 31·78	− 22	−50·6
L. 7. 1	P. 1448	9 1·9	52 0 16·56	− 35	+12·7
2	A.G.C. 3354	13·5	52 52 5·58		−39·1
3	P. 1476	13·8	51 40 48·22	+137	+32·2
4	A.G.C. 3380	18·1	51 59 55·34		+13·1
5	P. 1509	28·0	52 29 30·71	− 37	−16·5

From observations of these stars seventy-one determinations of the latitude have been derived. All the stars in each of the groups L. 1, L. 2, and L. 7 were taken on one plate. Since the exposures are made for one minute, while a star is crossing a wire, the total exposure of a plate to the sky is about 10 minutes.

When the Moon is nearly full and very bright this causes a slight fogging of the plate, but not sufficient to seriously impair the definition of the faintest stars used; that is, of magnitude 6·6 on the scale of the Draper Catalogue. The sums of the zenith distances in the groups L. 1 and L. 7 are $-0'\cdot 7$ and $+2'\cdot 4$ respectively, and the mean latitudes derived from them are therefore nearly independent of scale value. The latitude given by the star L. 2 *x* has been found by measuring the distance of its trail from the zenith point given by the trails of the stars 3 and 5. The agreement of the values thus found shows that this procedure is capable of giving accurate results. In the next table the seconds of the latitude are given under the number of the star, together with the approximate zenith distance.

TABLE I.

L. 2.	1 $-40'\cdot 3$.	2 $-64'\cdot 1$.	3 $+3'\cdot 4$.	4 $-29'\cdot 9$.	5 $+44'\cdot 7$.	6 $-53'\cdot 1$.	*x* $-83'\cdot 0$.	L. 5. $+25'\cdot 4$.	L. 6. $-50'\cdot 6$.
	″	″	″	″	″	″	″	″	″
Feb. 3	...	...	...	...	...	...	...	51·05W.	
6	50·40W.	51·40W.	...	...	52·14 E.	...	52·57 E.	...	...
10	50·42 E.	50·93 E.	51·04W.	52·15 E.	...	...	...	...	...
11	50·69W.	51·72W.	50·60 E.	51·89W.	52·51 E.	...	52·16 E.	51·33 E.	51·88 E.
12	49·84 E.	50·89 E.	50·90W.	52·62 E.	51·97W.	50·83E.	52·34W.	...	...
13	50·48W.	51·50W.	50·77 E.	52·11W.	52·90 E.	51·21W.	52·91 E.	51·56W.	51·98W.
Mean	50·37	51·29	50·83	52·19	52·38	51·02	52·50	51·31	51·93

TABLE II.

L. 1.	1 $-8'\cdot 9$.	2 $+15'\cdot 0$.	3 $-54'\cdot 6$.	4 $+22'\cdot 6$.	5 $+25'\cdot 2$.	Mean
	″	″	″	″	″	″
Jan. 22	51·52W.	52·04 E.	51·25W.	51·93 E.	...	51·90
31	51·03 E.	52·35W.	51·49 E.	51·64W.	52·78 E.	51·88
Feb. 1	...	51·80 E.	51·51W.	51·74 E.	52·39W.	51·75
Mean	51·28	52·06	51·42	51·77	52·59	51·85

L. 7.	1 $+12'\cdot 7$.	2 $-39'\cdot 1$.	3 $+32'\cdot 2$.	4 $+13'\cdot 1$.	5 $-16'\cdot 5$.	Mean.
	″	″	″	″	″	″
Feb. 2	51·75W.	50·71 E.	50·52 E.	50·49W.	50·64 E.	50·82
3	52·06 E.	51·22W.	51·38W.	51·05 E.	51·36W.	51·41
5	51·52W.	50·92 E.	50·97 E.	50·80W.	50·75 E.	50·99
11	51·56W.	50·90 E.	50·42 E.	50·58W.	51·37 E.	50·97
13	51·95 E.	51·13W.	50·84W.	50·97 E.	51·48W.	51·27
Mean	51·77	50·98	50·83	50·78	51·12	51·09

It will be seen from this table that in no case do the values of the latitude determined from the same star differ by as much as $1''\cdot 0$, even for such considerable zenith distances as 1 degree.

The probable error of one determination from all the values above is $\pm 0''.200$, but it will be noticed that there is a large systematic difference between the values found for circle east and circle west, which considerably increases the probable error. Thus the differences for the five stars in L. 7 in the sense E.—W. are

1	$+0''.40$	4	$+0''.45$
2	-0.34	5	-0.50
3	-0.47		

If a correction of $\pm 0''.20$ is applied to the values of the latitude in this group according as the circle is west or east, the probable error of a single determination is reduced to $\pm 0''.115$, which is smaller than the value found by a skilful observer with a visual telescope, viz. $\pm 0''.125$. If, now, the differences from the daily mean are found for each of the five stars, and the mean difference for each star is applied as a correction to every determination of the latitude by that star, the following values are found :—

L. 7.	1	2	3	4	5	Mean.
	$''$	$''$	$''$	$''$	$''$	$''$
Feb. 2	51.27	51.02	50.98	51.00	50.81	51.02
3	51.18	51.13	51.44	51.16	51.13	51.21
5	51.04	51.23	51.43	51.31	50.92	51.19
11	51.08	51.21	50.88	51.09	51.14	51.17
13	51.07	51.04	50.90	51.08	51.25	51.07

An explanation of the difference E.—W. has yet to be found; but its existence seems to be so conclusively shown that the above may be taken as an example of the result to be expected from the instrument.

Note accompanying Photographs of the Spectrum of Nova Persei. By Frank McClean, LL.D., F.R.S.

The observations made by me of the spectrum of *Nova Persei* at present extend from February 25 to March 6. On the 23rd and 24th the star was not visible. On the 25th some glimpses of the spectrum were obtained through passing gaps in the clouds. The star was then considerably brighter than *α Persei*. The general character of its spectrum did not subsequently change, although apparently the red hydrogen line became brighter.

From February 27 till March 3 photographs of the spectrum were obtained by me on each night with the 12-inch object glass prism, and again on March 5 and 6.

The two enlarged spectra exhibited were taken on February 27 and March 3. In extent, they reach from (Hζ) to the position of the (*b*) line of magnesium. Comparison spectra of *Sirius* and *β Crucis* are mounted on the same plate. The hydrogen series are at once identified in the spectrum of *Nova*. They appear both as ill-defined absorption lines and as broad bright bands, displaced towards the red, but joining up to the dark lines.

The helium series of lines do not appear with any certainty either as bright or as dark lines or bands.

The calcium (K) line is present, and there are other absorption bands which appear to be partly due to calcium and titanium. There are also other indistinct bright bands which have not been identified.

On the second photograph, taken on March 3, when the star had diminished somewhat in brightness, the spectrum remains the same, except that some of the dark bands have become more prominent.

The comparison with the spectrum of *Sirius* shows a certain correspondence between the grouping of the absorption lines in that spectrum and the dark bands in the spectrum of *Nova*. The correspondence is far from clear, but it is sufficient to suggest the idea that *Nova* is a Sirian star with additional bright bands due in the main to hydrogen. The displacement of the bright hydrogen bands to the less refrangible side of the absorption lines and their great width is attributed to differences of velocity in the line of sight between two or more sources of light. It should be observed, however, that in the case of *Nova Aurigæ* the bright bands were displaced in the same direction. No definite observations on this point appear to have been made with regard to *Nova Cygni* or *Nova Coronæ*. If the displacement is to be accounted for by differences of velocity, it should be as often one way as the other.

I hope to obtain some further photographs of the spectrum of *Nova* before it disappears, and will then place the full series before the Society.

1901 *March* 8.

Notes on the Spectrum of Nova Persei observed at the Stonyhurst College Observatory.

By the Rev. Walter Sidgreaves, S.J.

On the night of February 28 the cloud-cover, which had been persistent since the 20th, suddenly thinned at 10·15 P.M. to a hazy clearness. The *Nova* appeared rather brighter than *α Persei*. The spectrum was observed with the direct vision spectroscope on the 15-inch O.G. equatorial, and two photographs were obtained, one with this spectroscope, the other with a 4-inch

objective prism of $22\frac{1}{2}°$ refractive angle, by Mr. Thorp of Manchester, mounted on the Cooke finder of nearly 4 inches aperture.

The following notes refer mostly to the latter photograph, and to another taken with the same prism on March 3, when the star was rather fainter than *Algol*, but the sky much clearer between passing clouds. The plates were Mawson Stellar Rapid, and the one used with the direct compound prism an Edwards Isochromatic.

1. *The continuous spectrum* of the *Nova* is remarkable for its strength in the ultra-violet beyond the hydrogen series. The relative intensity here is such that if the rest of the spectrum were in accord with the sensibility curve of the plate, the blue region should be represented by a silver deposit darker than the darkest bands between Hβ and Hγ. This of itself would suggest that the dark bands of the negative between the hydrogen lines are not radiation lines, and that the spaces between them are absorption lines. But there is conclusive evidence on the plates that this is not the true interpretation of the spectrum. The continuity of the spectrum can be traced all along the photographs; and the region near Hβ on the violet side removes all doubt: this is undoubtedly continuous spectrum, and the silver density is quite in keeping with the paler spaces up to the Hθ, where it ceases to fade as rapidly as in other photographs of both white and yellow stars.

2. *The hydrogen lines* are very brilliant and very broad. The first three were easily seen on both dates without the aid of a cylindrical lens, Hα attracting the eye immediately. On the photographic plates Hβ is very intense, and the intensity of the others decreases in succession up to Hζ inclusive. Hη is nearly as strong as Hζ, while Hθ and Hι are much weaker and equal. Hι is the last of the series, although the continuous spectrum is very distinct considerably beyond this position. There are, however, two exceedingly feeble bright bands near, but the spaces between are nearer the positions of Hκ and Hλ.

Hβ, Hγ, Hδ, and Hη have certainly absorption companions on their violet sides. They are narrow compared with the bright lines. The apparent absorptions near the other lines may be mere contrast effects, but on the enlarged positive they look like decided absorptions.

The first four hydrogen bright lines β, γ, δ, and ϵ are sharper on their violet sides, and shade off towards the red side. Hη has the same appearance; but I think this line must be superposed on another bright band: it is out of proportion in breadth if the shading wing be considered part of the same line.

Hβ, Hδ, and Hζ, are each divided by a fine absorption line nearly central, and Hγ is probably divided in the same way.

The other bright lines of the spectrum are broad like the hydrogen lines. There are three very prominent ones besides narrower lines between D and F on the Isochromatic plate; and

on the Mawson plate there are four between $H\beta$ and $H\gamma$, and four also between $H\gamma$ and $H\delta$, one of which adjoins $H\delta$; and one, the calcium line K, between $H\iota$ and $H\zeta$.

The Isochromatic plate was exposed under rather worse atmospheric condition: the haze was thickening, and the star low down. The photograph is weak and the definition not good. But the positions of 14 lines were found to agree closely with those of *Nova Aurigæ* in 1892 February. The λ curve for the objective prism has not yet been plotted.

On the New Star in Perseus. By A. Stanley Williams.

A photograph of the region including *Nova Persei* was obtained here on the night of February 20 with a 4·4-inch Grubb portrait lens, and an exposure of 47 minutes (1901 February 20, $10^h\ 40^m$ to $11^h\ 27^m$ Greenwich mean time). There is no certain trace of the *Nova* visible upon this plate, which shows distinctly stars down to about the 12th magnitude, so that it must have been fainter than this at the time the photograph was taken. When discovered by Dr. Anderson on February 21 at $14^h\ 40^m$, the star had already attained a magnitude of 2·7, so that in an interval of not more, and probably less, than 28 hours a rise of about $9\frac{1}{2}$ magnitudes at least must have occurred.

Similar photographs were obtained on 1901 January 15 and 25 and February 11, on none of which is any certain trace of the star to be seen. There are two or three very minute stars visible near its place, but none of them appear to occupy exactly the same position.

The following eye-estimates of the brightness of the *Nova* were made by the writer.

1901 February 25, $11\frac{1}{2}^h$, *Nova* about midway between *Capella* and *α Persei*, but sky never perfectly clear.

	h	
Feb. 26	$11\frac{1}{2}$	3 steps brighter than *α Persei*
Feb. 28	10	3 steps brighter than *α Persei*
Mar. 1	$9\frac{1}{2}$	5 steps fainter than *α Persei*
Mar. 1	12	7 steps fainter than *α Persei*
Mar. 3	7 10^m	6 steps below *α Persei*, 2 steps below *β Persei*, 10 steps above *δ Persei*

In all these observations there was a bright Moon. On March 1 the *Nova* was also thought to be about equal to *Algol*, but comparison was unsatisfactory, owing to the difference in the colours of the two stars. Adopting the H.P. magnitudes of the comparison stars, and assuming the value of a step to be 0·1 mag-

nitude, the following will be the provisional brightness of the new star on the H.P. scale :—

1901 Feb. 25	$11\frac{1}{2}^{h}$	mag.	=1·06
„ 26	$11\frac{1}{2}$	„	=1·64
„ 28	10	„	=1·64
Mar. 1	$9\frac{1}{2}$	„	=2·44
„ 1	12	„	=2·64
„ 3	7 10^{m}	„	=2·41

Judging from its powers of penetrating through cloud, the *Nova* was thought to be comparable with *Capella* on February 23. Its colour also appeared to be the same. With a $2\frac{3}{4}$-inch refractor the colour was noted as intense bright white on February 25, as yellowish on February 26, and as white—with perhaps a tinge of yellow—on March 3. With the naked eye, aided by spectacles, the colour has always been distinctly yellowish.

Hove: 1901 March 4.

A First Note on the Nova in Perseus. By Professor K. D. Naegamvala, M.A.

On the afternoon of February 25 the following telegram was received from Captain Molesworth, R.E., stationed at Trincomali, in Ceylon :—

"First magnitude star, *Perseus*, right ascension 3·24, declination north 44. Kindly reply whether *Nova* and examine spectrum."

The weather here has been very unfavourable of late, the sky being often overcast, and fleecy clouds present as a rule throughout. A single glance the same evening, however, left no doubt that the star was a *Nova*, fully as bright as *β Geminorum*. It was photographed with a 4-inch portrait lens with one minute's exposure, and a preliminary examination with a Vogel eyepiece spectroscope revealed a bright-lined spectrum. Two spectrograms were also taken the same evening with a prismatic camera composed of a Cooke triple objective of 93-inch focus and a prism of 45°. Owing to an unfortunate maladjustment of the prism the plates came out blank on development.

The next evening (February 26), and on the two following, the *Nova* was carefully observed with Vogel and McClean spectroscopes of varying dispersion applied to the 16-inch guiding

telescope of the photographic reflector of the observatory, and the following is the summary of the observations. To avoid any bias I purposely refrained from referring to the previous observations of *Nova Aurigæ*, which were not consulted till yesterday.

There is a bright band in red (C), one in yellow (D_3), four in green, and two in blue.

There are four maxima at least in green. The maximum of brightness in the spectrum is in the extreme green, *i.e.* towards the violet.

The last band in blue is broadest, the last of four in green ($H\gamma$) comes next, then the first (of the two bands) in blue ($H\delta$), then C.

The last band in green ($H\gamma$) is brightest, then the last in blue ($H\epsilon$?), then in red ($H\beta$), and then the first in blue ($H\delta$).

Black bands on the violet or more refrangible sides of all the above bright bands except to "$H\epsilon$?" This absence of a black band is most probably due to the great falling off of the continuous spectrum in this region. The black band of $H\delta$ was intensest; next came that of $H\gamma$, and then of $H\beta$. The bright D_3 has also a black companion.

There is a faint broad bright band in the middle of the red portion of the spectrum, resolvable by glimpses into lines. Besides this there is also a very fine bright line in red nearer to $H\beta$, with a companion dark line.

The visible magnitude of the *Nova* on February 26 was about equal to that of β *Geminorum*, on the 27th less than β but greater than α *Geminorum*, while on the 28th it was certainly not greater than α *Geminorum*.

Four spectrograms have been secured during the last three evenings. These show at least sixteen maxima and minima of bright radiations between the region $H\beta$ and K(Ca), each accompanied by a dark companion. I defer for the present their discussion, but a casual comparison with the spectra of *Sirius* and *Capella* taken with the same instrument incontestably testifies to large shifting of the bright bands towards the less refrangible side of the spectrum; the black companions are also in all probability shifted in the opposite direction.

Maharaja Takhtasingji Observatory, Poona:
1901 *March* 1.

Positions of Nova Persei and 159 *Stars within* 25′ *distance from it. From a Photograph taken at the University Observatory, Oxford.* By F. A. Bellamy, F.R. Met. Soc.

After the receipt of the telegram announcing the discovery of the new star in *Perseus* the weather in Oxford was unfavourable, but on February 25, though very cloudy, there were rifts in the clouds, during which I saw *Nova* at its full brilliancy, and though the star was invisible to the eye most of the time the exposures were made, I was able to secure two plates with seven exposures, between 10^s and 13^m exposure, the star being visible all the time in the $12\frac{1}{4}$-inch refractor, used as a guiding telescope for astrographic work, sometimes as faint as a third or fourth magnitude star.

The plates taken were—

1727. Exposures, 10^s, 2^m, 2^m, 15^s between Oxf. Sid. T. $5^h\,13^m\,7^s$ and $5^h\,21^m\,17^s$.

1728. Exposures, 220^s, 8^m, $13\frac{1}{4}^m$ between Oxf. Sid. T. $6^h\,20^m\,7^s$ and $6^h\,56^m\,42^s$.

On the second plate a trail for ten minutes was also given.

Plate 1728 was measured by Mr. E. A. Gray, with the glass scale micrometer, in one of the instruments used for the astrographic catalogue, first in the direct, then in the reversed position, so as to eliminate personality, and all three exposures were measured for the stars used in determining the plate constants and the *Nova*; but for the other stars given in the subjoined catalogue only the second and third exposures were measured, the majority of the faint stars not being visible with the short exposure, owing to cloud.

The places of all stars which could be found in the Bonn A.G. Catalogue (+40° to +50°) within the area covered by the plate were brought to the epoch 1900·0, and standard coordinates (ξ and η), with reference to the adopted plate centre R.A. $3^h\,25^m$ +44° 0′, were computed by means of the formulæ given in *Monthly Notices*, liv. 11.*

The Oxford measures x, y (reckoned from the *corner* of the réseau, not the centre) were compared with these coordinates, equations formed and solved in the usual way, and the constants were found to be—

a	b	c (R.I.)	d	e	f (R.I.)
+·00031	+·00539	−14·3491	−·00528	+·00031	−14·3797

where $\xi = x\,(1+a) + by + c$, $\eta = dx + (1+e)\,y + f$.

In Table I. are collected these computed R.A.'s and Dec.'s, the corrections deduced from this plate, and the Oxford standard coordinates ξ' and η'. This information may be useful to others.

* Tables for simplifying the use of these formulæ for 0° to 75° have been prepared and will soon be printed.

TABLE I.

Bonn A.G.O.	Mag.	R.A. 1900·0. h m s	Oxf.–Bonn. s	N. Dec. 1900·0. ° ′ ″	Oxf.–Bonn. ″	$\xi'=\xi+13$. R.I.	$\eta'=\eta+13$. R.I.
2883	7·9	3 20 8·46	−0·04	43 18 19·0	+0·7	2·3894	4·7425
2892	9·0	3 20 32·68	−0·09	43 22 27·4	+1·8	3·2801	5·5618
2895	8·6	3 20 54·84	−0·02	43 49 37·7	−1·0	4·1556	10·9769
2898	8·3	3 21 13·98	+0·15	44 2 31·5	+0·4	4·8816	13·5527
2899	9·0	3 21 14·69	+0·04	43 59 31·6	−2·2	4·8964	12·9441
2906	7·2	3 21 29·67	+0·12	44 1 43·7	+0·3	5·4429	13·3870
2907	8·9	3 21 34·92	0·00	43 38 39·2	+0·3	5·5797	8·7697
2911	7·7	3 21 46·67	0·00	43 24 21·3	−0·4	5·9765	5·9035
2913	8·2	3 21 52·65	+0·01	44 18 3·0	−0·3	6·2959	16·6410
2919	8·4	3 22 22·44	+0·08	44 42 9·6	−0·7	7·4030	21·4528
2944	8·7	3 23 44·27	0·00	44 29 19·3	−0·1	10·2986	18·8695
2948	9·0	3 24 3·23	−0·06	43 38 29·4	+0·7	10·9438	8·7031
2953	9·0	3 24 17·74	−0·15	43 51 59·1	−1·0	11·4713	11·3953
2956	8·7	3 24 29·11	−0·04	44 18 43·0	+0·5	11·8935	16·7457
2964	8·5	3 24 47·37	+0·03	44 11 29·7	+0·7	12·5482	15·3013
2968	8·9	3 25 1·70	−0·03	44 3 34·5	+0·2	13·0599	13·7156
2970	9·2	3 25 12·46	−0·03	44 28 18·5	0·0	13·4437	18·6618
2971	9·0	3 25 12·72	+0·12	44 37 16·6	+0·1	13·4569	20·4556
2972	8·8	3 25 14·39	+0·55	43 19 56·2	−1·3	13·5434	4·9831
2973	7·6	3 25 24·80	−0·09	44 29 58·7	+0·2	13·8813	18·9969
2979	6·5	3 25 47·09	+0·04	44 30 56·4	−0·1	14·6804	19·1899
2982	8·9	3 25 58·20	−0·09	43 53 43·4	+0·7	15·0939	11·7500
2983	8·9	3 26 4·87	+0·33	43 25 16·5	+0·4	15·3680	6·0598
2986	8·9	3 26 13·77	−0·02	43 15 45·8	−0·4	15·6855	4·1558
2996	9·1	3 27 3·65	−0·16	43 30 45·2	+0·8	17·4781	7·1669
3004	9·1	3 27 24·91	−0·01	43 24 19·9	−0·2	18·2637	5·8846
3008	9·0	3 27 45·33	−0·15	44 14 52·7	−0·4	18·9162	15·9991
3009	6·9	3 27 50·20	−0·14	44 28 2·0	−1·5	19·0686	18·6283
3016	8·5	3 28 31·81	−0·18	43 30 46·1	+1·1	20·6743	7·1978
3021	8·9	3 28 51·01	+0·04	42 57 22·2	−0·2	21·4566	0·5203
3034	8·9	3 29 56·53	−0·09	43 44 41·3	+0·4	23·7084	10·0187

When two exposures only are used (as in the case of 159 stars in the annexed catalogue) the constants *c* and *f* become

c R.I.	*f* R.I.
−14·3473	−14·4795

a, *b*, *d*, *e* remaining sensibly unchanged.

These mean measures were corrected for the plate constants, the quantities being carried to the fourth decimal place throughout, and were converted into differences of R.A. and Dec. A catalogue of these stars is given at the end of this paper.

Owing to the great diameter of the image of *Nova* on the plate (35″ to 50″) special care was taken to render the mean measures in x and y as exact as possible. Each image was bisected and two contact measures made in both positions of the plate by Professor Turner, H. F. Mullis, B. Gray, E. A. Gray, and myself. The mean of the whole series of 45 measures each in x and y was taken. The resulting means for 1900·0 are

ξ' R.I.	η' R.V.
12·9956	9·1883

which, corrected for constants already mentioned for the mean of three exposures, give

R.A. $3^h\ 24^m\ 24^s{\cdot}12$ Dec. $+43^\circ\ 33'\ 39''{\cdot}51$

There appears not to be any star brighter than about the 12th mag., or nearer to the *Nova* than 4′, unless the brilliancy of the star, approximately equal to *Aldebaran*, obliterated some faint stars within 30″ of *Nova*. Photographs when *Nova* is below the 6th mag. would soon decide this point. It may be mentioned that photographs taken on February 27 and March 5 do not show other stars nearer.

Some estimations of magnitude have been made, and the following notes are extracted from the note-book.

Feb. 25. 8^h. To the eye the colour was white, with possibly a tinge of yellow. In the $12\frac{1}{4}$-inch refractor the colour appeared as emerald or young grass green. Mag. about 1·3.

Feb. 27. $7\frac{1}{2}^h$. *Nova*=β *Tauri*, also equal to the brightest star in *Orion's* belt, nearly $\frac{1}{2}$ mag. brighter than α *Persei*.

Feb. 28. 10^h. *Nova* certainly brighter than α *Persei*.

Mar. 1. 7^h. *Nova*=α *Persei* and β *Aurigæ*, slightly fainter than β *Tauri*; colour slightly orange; had not seen this tinge on other nights. Plate taken in a small camera to locate the position of *Nova* in the constellations *Perseus*.

Mar. 5. 7^h *Nova*=δ *Cassiopeiæ*.

Mar. 6. 8^h *Nova*=ϵ *Persei*, or 0·1 or 0·2 fainter; orange.

Mar. 7. 12^h *Nova*=γ and δ *Persei*, less orange in colour.

I should like to express my thanks to Mr. H. F. Mullis, Mr. B. Gray, and Mr. E. A. Gray for assistance they have given beyond the usual hours at the observatory, thus making it possible to get these results completed in so short a time.

The stars in Table II. are situated within about five réseau intervals of the *Nova*, and may serve as points of reference should the star decrease to a fainter magnitude than the tenth. On account of the cloud it is not easy to decide what is the limit of magnitude of these 159 stars; probably, judging from the

number of stars on the whole plate (over 1200), stars of less than the 12th mag. are on the plate.

Col. 1. The catalogue number: those with ✱ are independent measures of two exposures of Bonn stars.

2. The measured diameter of the star's image, the quantity given being the mean of four separate measures; unit ·001 of a réseau interval.

3–4. The standard coordinates, ξ', η', for 1900·0; *i.e.* from the (S.W.) corner of the plate, with centre $3^h\ 25^m + 44°$.

5–6. The deduced R.A.'s and Dec.'s for 1900·0.

TABLE II.

Ref. No.	Oxford Measured Mag.	ξ' 1900·0. R.I.	η' 1900·0. R.I.	Deduced R.A. 1900·0. h m s	Deduced N. Dec. 1900. ° ′ ″
1	7	6·7173	5·2152	3 22 7·22	43 20 56·6
2	6	6·7805	6·8797	22 8·56	29 16·0
3	7	6·8289	2·6972	22 10·88	8 21·6
4	5	6·8762	2·6530	22 12·19	8 8·5
5	12	7·0318	11·2263	22 14·49	51 0·5
6	10	7·1473	8·9722	22 18·20	39 44·6
7	10	7·1594	4·4411	22 19·55	17 5·4
8	6	7·1752	5·1646	22 19·82	20 42·5
9	10	7·2800	2·6128	22 23·26	7 57·4
10	8	7·4228	9·0376	22 25·80	40 4·8
11	11	7·4178	4·7023	22 26·59	18 24·4
12	6	7·7115	2·7717	22 35·05	8 46·0
13	9	7·7523	4·1085	22 35·90	15 27·1
14	7	7·8908	12·1423	22 38·12	55 37·2
15	7	7·8472	4·6643	22 38·40	18 14·0
16	10	7·9722	10·1806	22 40·77	45 48·9
17	7	8·0104	6·5116	22 42·53	27 28·4
18	9	7·9932	2·8825	22 42·75	9 19·8
19	7	8·0550	6·6181	22 43·74	28 0·5
20	9	8·2079	11·8330	22 46·99	54 5·1
21	12	8·2567	5·8006	22 49·44	23 55·6
22	5	8·3181	11·7280	22 50·06	53 33·8
23	12	8·3504	8·3742	22 51·56	36 47·8
24	7	8·3684	4·1699	22 52·81	15 46·7
25	5	8·3830	3·7626	3 22 53·28	43 13 44·6

Ref. No.	Oxford Measured Mag.	ξ' 1900·0.	η' 1900·0.	Deduced R.A. 1900·0.	Deduced N. Dec. 1900.
		R.I.	R.I.	h m s	° ′ ″
26	8	8·4671	5·9987	3 22 55·20	43 24 55·5
27	11	8·6731	9·6113	23 0·27	42 59·5
28	8	8·6678	3·7991	23 1·09	13 56·0
29	9	8·7229	11·4830	23 1·34	52 21·1
30	11	8·7189	9·0150	23 1·64	40 0·7
31	8	8·7840	9·6431	23 3·34	43 9·2
32	12	8·7982	11·0677	23 3·50	50 16·6
33	11	8·9406	11·1344	23 7·43	50 36·9
34	11	9·2346	11·6606	23 15·51	53 15·2
35	6	9·1905	3·0091	23 15·55	10 0·0
36	6	9·2458	3·5278	23 16·99	12 35·6
37	12	9·3510	8·4360	23 19·19	37 8·1
38	9	9·4696	11·5707	23 22·04	52 48·6
39	8	9·4789	5·9639	23 23·06	24 46·7
40	8	9·5351	11·4722	23 23·87	52 19·1
41	10	9·8003	2·6865	23 32·31	8 24·1
42	9	9·8423	10·5063	23 32·51	47 29·8
43	5	9·8394	6·0751	23 32·97	25 20·6
44	7	9·9197	10·2003	23 34·69	45 58·1
45	7	9·9569	12·5492	23 35·45	57 42·8
46	13	9·9266	4·4235	23 35·57	17 5·2
47	7	9·9629	12·9249	23 35·57	59 35·6
48	11	10·0321	5·8032	23 38·31	23 59·2
49	6	10·0384	3·8849	23 38·70	14 23·8
50	7	10·0676	7·5783	23 39·09	32 51·8
51	7	10·0665	7·0465	23 39·12	30 12·2
52	6	10·1167	2·9157	23 40·96	9 33·2
53	10	10·3730	3·4441	23 47·93	12 12·0
54	7	10·4252	4·3225	23 49·27	16 35·6
55	8	10·5363	3·6787	23 52·39	13 22·5
56	8	10·6322	3·1005	23 55·07	10 29·2
57	9	10·6929	5·2312	23 56·55	21 8·4
58	8	10·8065	12·7476	23 59·04	58 43·3
59	10	10·8263	7·4506	24 0·03	32 12·7
60	6	10·9199	12·7604	3 24 2·19	43 58 47·2

Ref. No.	Oxford Measured Mag.	ξ' 1900·0.	η' 1900·0.	Deduced R.A. 1900·0.			N. Dec. 1900.		
		R.I.	R.I.	h	m	s	°	′	″
61*	23	10·9444	8·7044	3	24	3·19	43	38	30·5
62	8	10·9546	6·9584		24	3·61		29	46·7
63	11	10·9804	3·3903		24	4·60		11	56·5
64	10	11·0230	8·1445		24	5·41		35	42·6
65	19	11·1991	2·4820		24	10·66		7	24·2
66	4	11·2059	2·5950		24	10·84		7	58·1
67	8	11·2278	3·8169		24	11·35		14	4·6
68*	21	11·4723	11·3945		24	17·62		51	57·9
69	8	11·4663	3·4237		24	17·92		12	6·8
70	8	11·5474	11·6873		24	19·69		53	25·7
71	11	11·6986	5·6089		24	24·19		23	2·4
72	8	11·7661	3·2378		24	26·16		11	11·2
73	8	11·7940	10·0356		24	26·61	43	45	10·4
74	12	11·8456	13·2607		24	27·89	44	1	17·9
75	8	11·9859	12·8550		24	31·81	43	59	16·3
76	11	12·0015	12·3662		24	32·26		56	49·7
77	10	12·0193	11·6728		24	32·78		53	21·6
78	6	12·0584	4·6838		24	34·12		18	25·1
79	10	12·1098	11·2389		24	35·31		51	11·5
80	7	12·2113	12·9048		24	38·07		59	31·3
81	7	12·4278	11·3322		24	44·13		51	39·6
82	18	12·4578	2·5827		24	45·14		7	55·0
83	8	12·5403	12·9355		24	47·22		59	40·6
84	6	12·5770	3·0904		24	48·40		10	27·3
85	6	12·7788	3·4829		24	53·93		12	25·1
86	14	12·7893	11·6964		24	54·15		53	28·9
87	6	12·7890	6·6892		24	54·18		28	26·8
88	10	12·8008	3·7202		24	54·53		13	36·2
89	7	12·8111	10·0030		24	54·77		45	0·9
90	6	12·8862	6·8995		24	56·86		29	29·9
91	8	12·8892	8·0304		24	56·94		35	9·2
92	12	12·9841	7·7705		24	59·56		33	51·2
93	9	12·9968	11·6668		24	59·91		53	20·0
94	14	13·2595	9·4534		25	7·18		42	16·0
95	9	13·3642	2·3603	3	25	9·98	43	6	48·3

Ref. No.	Oxford Measured Mag.	ξ′ 1900·0.	η′ 1900·0.	Deduced R.A. 1900·0.	Deduced N. Dec. 1900.
		R.L	R.L	h m s	° ′ ″
96	14	13·3811	4·4926	3 25 10·47	43 17 27·9
97	6	13·3843	4·0044	25 10·55	15 1·4
98*	24	13·5435	4·9816	25 14·94	19 54·5
99	7	13·5778	4·9449	25 15·89	19 43·5
100	6	13·5923	12·4022	25 16·45	57 0·6
101	10	13·6359	10·0676	25 17·61	45 20·2
102	11	13·7104	12·5763	25 19·74	57 52·8
103	10	13·9074	6·7923	25 25·01	28 57·6
104	9	13·9659	12·9999	25 26·86	59 59·8
105	6	14·0701	2·5359	25 29·32	43 7 40·8
106	6	14·0610	13·1492	25 29·51	44 0 44·5
107	7	14·0800	2·6106	25 29·60	43 8 3·2
108	20	14·2295	3·2584	25 33·72	11 17·4
109	7	14·2716	5·7370	25 35·00	23 40·8
110	5	14·3264	12·8717	25 36·87	59 21·2
111	8	14·3598	5·3492	25 37·40	43 21 44·5
112	12	14·3856	13·0664	25 38·53	44 0 19·5
113	9	14·4394	4·4720	25 39·55	43 17 21·3
114	15	14·5152	3·0429	25 41·55	10 12·6
115	8	14·5236	3·9149	25 41·83	14 34·1
116	6	14·5929	11·0541	25 44·17	50 15·7
117	8	14·6687	4·1886	25 45·83	15 56·2
118	6	14·7698	3·6915	25 48·57	13 27·0
119	8	14·7985	4·8313	25 49·44	19 8·8
120	12	14·8120	3·5903	25 49·72	12 56·6
121	6	14·8178	6·8969	25 50·11	29 28·4
122	9	14·8286	4·1124	25 50·21	15 33·2
123	12	14·9275	10·8343	25 53·43	49 9·5
124	11	14·9971	2·5778	25 54·72	7 52·8
125	9	14·9949	8·2309	25 55·10	36 8·5
126	9	15·1112	4·3140	25 57·99	16 33·4
127*	23	15·0958	11·7507	25 58·17	53 44·3
128	11	15·1287	8·1836	25 58·79	35 54·2
129	7	15·1304	7·6805	25 58·79	33 23·3
130	7	15·1230	12·0526	3 25 58·95	43 55 14·8

Ref. No.	Oxford Measured Mag.	ξ′ 1900·0.	η′ 1900·0.	Deduced R.A. 1900·0.	Deduced N. Dec. 1900.
		R.I.	R.I.	h m s	° ′ ″
131	6	15·1675	3·2436	3 25 59·45	43 11 12·3
132*	15	15·3678	6·0602	26 5·20	25 17·0
133	6	15·4797	4·4407	26 8·12	17 11·1
134	10	15·4767	7·2063	26 8·30	31 0·7
135	6	15·4705	9·6744	26 8·37	43 21·1
136	8	15·5793	7·6033	26 11·17	32 59·6
137	14	15·5873	5·6428	26 11·20	23 11·5
138	6	15·6301	7·9657	26 12·61	34 48·3
139	11	15·6248	12·4511	26 12·92	57 13·9
140	8	15·6418	9·6890	26 13·11	43 25·3
141	11	15·6509	12·9037	26 13·69	59 29·6
142*	22	15·6853	4·1553	26 13·74	15 45·2
143	8	15·7943	3·6361	26 16·68	13 9·4
144	12	15·7959	10·3846	26 17·45	46 53·8
145	8	15·8216	4·8806	26 17·56	19 22·7
146	10	15·8024	12·8268	26 17·90	59 6·4
147	7	15·8594	12·6533	26 19·46	58 14·3
148	19	15·9696	10·8286	26 22·31	49 6·8
149	9	16·0421	8·3544	26 24·03	36 44·4
150	8	16·1822	4·7090	26 27·46	18 30·8
151	6	16·2940	8·3478	26 30·99	36 42·1
152	9	16·3105	11·2022	26 31·81	50 58·4
153	9	16·3634	9·6309	26 33·07	43 6·9
154	12	16·4251	4·9172	26 34·15	19 32·9
155	6	16·4982	3·9712	26 36·04	14 46·0
156	6	16·4896	9·0373	26 36·48	40 8·7
157	9	16·5915	8·2546	26 39·19	36 13·8
158	6	16·7032	9·7561	26 42·49	43 44·0
159	7	16·7079	12·4399	3 26 43·01	43 57 9·1

Some years ago I was engaged in making estimations of *Nova Aurigæ* when it fell below the ninth to the 13·5 magnitude; the accurate or even approximate positions of the surrounding stars were not to be found in any catalogue, the faintness of most of the stars used for comparison rendered their observation with the transit circle impossible; one had thus to resort to the

less accurate and very tedious process of determining their positions by means of a lower power eyepiece furnished with a ring, letter N, or cross-bar micrometer, which would permit observation of faint stars in a dark field. I remember giving many fine nights, spread over some weeks, to approximately fixing the positions of a comparatively small number of stars about the *Nova*, and I likewise spent a good deal of time for the same purpose in the region surrounding the supposed position of Tycho Brahe's *Nova* of 1572, and intended to proceed in a similar way with other regions about "new" stars; but the tediousness of those methods of observation did not seem to justify one, in view of other and more important work, in expending more time over it, so it was never completed.

With modern methods which have rendered such work so easy I could not let pass the opportunity of securing *photographs* of *Nova Persei* and neighbouring stars at the earliest possible moment.

Observations of the New Star in Perseus made at the Radcliffe Observatory, Oxford.

(*Communicated by Arthur A. Rambaut, M.A., Sc.D., F.R.S., Radcliffe Observer.*)

Since the receipt of the telegram announcing its discovery, observations have been made of Dr. Anderson's new star at the Radcliffe Observatory on every evening that the weather permitted.

On February 23 and 24 the sky was almost continuously overcast, and the star was not seen by us until the evening of the 25th. At this time its magnitude appeared to be 0·9.

The observations include transit-circle determinations of the position of the star on four afternoons, a spectroscopic examination of the light on two evenings, measures of its brightness made with a wedge photometer, and eye-estimates of its brightness as compared with several of the brighter stars.

The transit-circle observations and photometric measures will be published in due time when they have been more fully discussed. The present notice is chiefly concerned with the eye-estimates of magnitude.

In making these comparisons the magnitudes of the Harvard Photometry have been adopted, and the observers have estimated the difference between the *Nova* and each comparison star in tenths of a magnitude. In the results given below no correction has been applied for the atmospheric absorption of light, but as, for the most part, the comparison stars have been taken at various altitudes both above and below the *Nova*, the effect of the absorption

would tend to be eliminated in the mean, and the results of the separate comparisons made on the same occasion show that the means may be relied on to within two or three tenths of a magnitude. On only one occasion was the correction for absorption applied. That was in the comparison made by A.A.R. with Rigel on February 26. At the time of the comparison this star was at a zenith distance of 69° 4′, and in this position the absorption of light would amount to nearly half a magnitude. When the correction for absorption was applied, however, this comparison agreed closely with the others.

The colour of the star has undergone a remarkable change during the short time it has been under observation. Whereas at the time of its discovery, and even up to February 25, when we first saw it, the colour was noted as being bluish white, it has been becoming notably redder from night to night. This change in the colour of the star makes eye-comparisons with the whiter stars a little difficult, and may be to some extent responsible for the differences between the estimates made by one observer and another.

It is, perhaps, premature to conclude that there have been variations in the rate of diminution of the light, but the irregularities in the curve of magnitudes seem to be rather greater than might be expected to arise from errors of observation.

In Table I., below, are given a number for reference, the names of the comparison stars used and the Harvard magnitudes on which our estimates are based.

Table II. contains the separate comparisons and remarks relating to the colour, &c.

Table III. contains the means of each observer's separate comparisons and the general mean for each night.

TABLE I.

List of Stars used for Comparison with Nova Persei.

Ref. No.	Name of Star.	Harvard Photom. Mag.	Ref. No.	Name of Star.	Harvard Photom. Mag.
1	Capella	0·18	13	β Tauri	1·90
2	Rigel	0·32	14	α Persei	1·94
3	Procyon	0·46	15	α Ursæ Maj.	1·96
4	α Orionis	0·91	16	η Ursæ Maj.	2·02
5	Aldebaran	1·00	17	β Aurigæ	2·07
6	Pollux	1·12	18	β Ursæ Min.	2·13
7	Regulus	1·42	19	γ Androm.	2·14
8	Castor	1·56	20	Polaris	2·15
9	ε Orionis	1·76	21	α Cassiop. (var.)	2·25
10	ε Ursæ Maj.	1·85	22	γ Cassiop.	2·30
11	γ Orionis	1·86	23	Algol (var.)	2·31
12	ζ Orionis	1·89	24	δ Orionis	2·36

Ref. No.	Name of Star.	Harvard Photom. Mag.	Ref. No.	Name of Star.	Harvard Photom. Mag.
25	ζ Ursæ Maj.	2·38	32	γ Ursæ Min.	3·18
26	β Cassiop.	2·42	33	δ Ursæ Maj.	3·41
27	γ Ursæ Maj.	2·56	34	ε Cassiop.	3·55
28	δ Cassiop.	2·84	35	η Cassiop.	3·64
29	ε Persei	3·04	36	ζ Cassiop.	3·74
30	γ Persei	3·11	37	η Persei	3·93
31	δ Persei	3·18			

TABLE II.

The following observations of magnitude and notes of colour were taken :—

1901.	G.M.T. h m	Obser-ver.	Refer-ence Stars.	Result-ing Mag.	1901.	G.M.T. h m	Obser-ver.	Refer-ence Stars.	Result-ing Mag.
Feb. 25	6 45	R.	1, 14	1·0	Feb. 25	7 0	W.	14	0·9
	7 0	W.	2	0·8		7 30	"	3	0·7
		"	14	0·9			"	8	0·6*
		"	23	0·8			"	1	0·9
		"	5	0·7			"	4	1·1
		"	4	1·0			"	3	1·0

Notes.

Observer R. Nova, bluish; Capella, yellow.

Observer W. The first six estimations were made with the 10-inch equatorial, with different powers, the remainder with naked eye. With power 100, colour of Nova bluish-white; occasionally a red marginal fringe is noticeable. Power 45: Algol, light yellow, no red fringe. Power 180: Nova, bluish-white; α Persei, light yellow; α Orionis, reddish-yellow; Aldebaran, strong yellow; Rigel, very blue.

Feb. 26	9 30	A.A.R.	23, 14, 8, 6, 2, 31	1·0	Feb. 26	10 0	W.	6	1·3
								7	1·4
	9 47	W.	5	1·2		10 35		3	1·5
			1	1·0				14	1·1
			14	1·4				17, 1	1·1
			23	0·6				4	1·4
			4	1·3				23	0·6
			17, 1	1·1		10 0	R.	14, 1	1·4

Notes.—Observer A.A.R. By method of sequence. At 9^h 30^m, observer C., Nova is about 0·25 mag. fainter than it was February 25 8^h.

1901.	G.M.T.	Observer.	Reference Stars.	Resulting Mag.	1901.	G.M.T.	Observer.	Reference Stars.	Resulting Mag.
	h m					h m			
Feb. 27	7 15	W.	14	1·6	Feb. 27	7 15	W.	17	1·6
			8	1·6*		7 20	R.	5	1·6
			5	1·5				14	1·5
			1	1.2				23	1·6

Note.—Observer W. The comparisons with Capella and β Aurigæ are approximate only. Clouds passing.

Feb. 28	7 0	R.	5	1·6	Feb. 28	8 0	W.	10	1·6
			14	1·6		8 10		20	1·8
			23	1·7		9 45	C.	14	1·4
	8 0	W.	14	1·7				23	1·5
			23	1·6				17	1·6
			17	1·8				8	1·0*
			1	1·9				20	1·4 (½ wt.)
			4	1·6				15	1·3 „
			5	1·4				10	1·3 „
			7	1·7				6	1·3
			15	1·7					

Notes.—Observer W. Twilight observation at $6^h\ 15^m$. Capella, very distinct; Nova, distinct; α Persei and Algol, invisible. At 6.30, α and ε Persei and Capella now visible. Nova appears brighter than α Persei and β Aurigæ. From 8^h moonlight strong, but Moon screened from observer.

Mar. 1	4 54	R.	14	1·9	Mar. 1	8 0	W.	9	1·4 (½ wt.)
	6 30	A.A.R.	14	2·0				24	2·0 (½ wt.)
			23	2·0				8	1·6*
	6 30	W.	14	1·9				20	2·4
			23	1·8				25, 16	2·2
	8 0	„	14	2·1				18	2·1
			23	2·0		7 15	R.	14	1·9
			17	1·9				23	2·0
			11	1·9		8 0	C.	14	1·9
			12	1·5 (½ wt.)		11 30	A.A.R.	23, 14	2·1

Notes.

Observed with transit circle, R. Nova yellow, with reddish tinge; α Persei yellow; strong contrast with Nova when at edge of field.

Observer W. Nova is reddish-yellow by contrast with α Persei and Algol. Strong moonlight troublesome. Comparison with Castor difficult; Moon near.

---

* Comparisons with Castor seem to indicate that the Harvard magnitude of this star is 0·3 mag. brighter than the Radcliffe estimations. On Feb. 27, 28, and Mar. 1, the Moon was near. The comparisons have not been used for Table III.

1901.	G.M.T.	Observer.	Reference Stars.	Resulting Mag.	1901.	G.M.T.	Observer.	Reference Stars.	Resulting Mag.
	h m					h m			
Mar. 2	12 0	R.	14	2·1	Mar. 2	12 0	R.	13, 14	1·9
			23	2·0					

Notes.—Nova is reddish; Algol and β Tauri are both bluish.

Mar. 3	9 15	R.	14	2·2	Mar. 3	9 15	R.	29	2·3
			13	2·0				31	2·3
			23	2·2					

Notes.—α Persei, yellow; Nova, reddish; Algol, blue.

Mar. 4 Cloudy.

Mar. 5	7 8	W.	14	2·4	Mar. 5	7 8	W.	34	2·5
			23	2·6				28	2·5
			17	2·4				22	2·5
			11	2·4				35	2·1
			12	2·1				21	2·3
			9	2·1				26	2·5
			24	2·2		7 8	R.	14	2·5
			8	2·0*				23	2·5
			20	2·4				29	2·6
			18	2·4				31	2·6

Notes.

Observed with transit circle, C. Nova reddish-yellow and fainter than α Persei.

Observer W. Moon very low in the east. Nova is very red to-night, equal to Aldebaran's tint.

Observer R. Nova is orange-red, deeper in colour than Aldebaran, α Orionis, or Mars. Algol is bluish-white.

Mar. 6	6 30	W.	23, 29	2·7	Mar. 6	8 15	W.	35	3·3
	6 50	R.	29	2·9				36	3·2
			31	2·9				19	2·6
			23	2·8				14	3·4
	8 15	W.	20	3·4				29	3·0
			18	3·3				31	2·9
			32	3·0				30	3·0
			34	3·1				37	3·4
			28	3·0		8 45		27, 33	3·0
			22	2·7		9 45	C.	31	3·0
			26	2·7				29	3·0
			21	2·6					

Notes.

Observer W. In strong twilight at $6^h\ 20^m$: Capella, β Aurigæ, and α Persei visible; Algol and Nova, as yet, invisible. At 6.30 Nova easily visible, but ϵ Persei seen only at times. At 8.15–45, stars scintillating; much haze; colour of Nova is decidedly red. Half weight should be given to comparisons with Polaris, γ Andromedæ, and α Persei.

Observer R. Observed in clear breaks.

TABLE III.

Means of Estimations of Magnitude of Nova Persei.

1901.	G.M.T. h m	Observer.	Mean Mags.	No. of Comparisons.	Adopted Magnitude for the Night.
Feb. 25	6.45	R.	1·0	2	
	7.30	W.	0·85	6 (Equatorial)	0·90
	7.30	W.	0·91	4 (Eye)	
26	9.30	A.A.R.	0·95	2	
	10.11	W.	1·17	13	1·17
	10.0	R.	1·4	2	
27	7.15	W.	1·47	4	1·50
	7.20	R.	1·53	3	
28	7.0	R.	1·65	3	
	8.5	W.	1·67	10	1·58
	9.45	C.	1·41	7	
Mar. 1	4.54	R.	1·94	1	
	6.30	A.A.R.	2·03	2	
	6.30	W.	1·88	2	
	7.15	R.	1·96	2	1·99
	8.0	W.	2·01	10	
	8.0	C.	1·94	1	
	11.30	A.A.R.	2·13	2	
2	12.0	R.	2·05	3	2·05
3	9.15	R.	2·20	5	2·20
5	7.8	W.	2·36	15	2·42
	7.8	R.	2·54	4	
6	6.30	W.	2·67	2	
	6.50	R.	2·88	3	2·95
	8.30	W.	3·03	17	
	9.45	C.	3·01	2	

The observers were : Dr. Rambaut, indicated by A.A.R.
Mr. Wickham, „ W.
Mr. Robinson, „ R.
Mr. McClellan, „ C.

Spectroscopic Observations.—On February 26 and March 5 the light of the star was examined with a small single prism spectroscope attached to the 10-inch Barclay equatorial. On February 26 we found a bright continuous spectrum on which were superposed several bright lines. The most conspicuous of these were one near the extreme red end of the spectrum which was taken to be C, one faint one in the orange (most probably D), and two in the green, of which the *less* refrangible was the brighter. The more refrangible of these lines was taken to be F, or possibly Hγ. There were several other faint lines not identified. A bright patch was noticed in the violet, which was so condensed as to suggest a bright line out of focus. There were strong absorption bands in the orange and green, which W. at one time thought could be resolved into a series of very close dark lines.

On March 5 the general appearance of the spectrum was very similar. The absorption in the red just above C (?) and in the blue just above F (?) was very strongly marked. The C (?) line was relatively much more brilliant than on February 26, which may account for the increased redness in the light of the star, while the *more* refrangible of the two green lines now appeared the brighter. Numerous other faint lines were noticed.

Radcliffe Observatory, Oxford:
1901 *March* 7.

Addendum.

The following estimations were made last night:—

1901.	G.M.T.	Observer.	Ref. Stars.	Resulting Mag.	Adopted Magnitude for the Night.
Mar. 7	11.50	W.	29	2·8	
			31	2·7	
	11.52	R.	29	2·7	2·77
			31	2·8	
			30	2·9	
			14	2·7	

Notes.

W.—I think Nova is brighter than last evening, and not nearly so red.

R.—Nova has brightened, and is very red, but stars' images are scintillating considerably.

Radcliffe Observatory, Oxford:
1901 *March* 8.

The Variable Star R Centauri. By Alex. W. Roberts, D.Sc.

The southern variable star *R Centauri* (Ch. 5096) is a very fine example of a distinct and well-defined type of long-period variation, the type where each full light period consists of a double maximum and double minimum.

There are long-period variables that exhibit no secondary phase whatever, their variation being very regular.

For example, *S Sculptoris*, *U Centauri*, *R*, *V Sagittarii*, *U Pavonis*, and *T Pavonis* belong to this type.

There are also stars that exhibit secondary phases at frequent but irregular intervals. A good example of this class is the southern variable L_2 *Puppis*.

There are, however, a few stars where the secondary phases occur with marked regularity as regards period, but some irregularity as regards magnitude. Of this class of long-period stars *R Centauri* is, I think, the best example among southern variables.

The variation of *R Centauri* was discovered by Gould in 1871.

From the date of its discovery till 1878 the star was under more or less regular observation at Cordoba. On this series of observations Dr. Gould remarks, *U. A.* p. 269 :—

"The observations might be reconciled by supposing a full period of 525 days, with epoch of principal maximum 1871 April 18, and two intermediate maxima following the principal one by 197 and 378 days respectively.

"But this is incompatible with the estimates $6\frac{1}{4}^{m}$ and 6^{m} made 1874 June 25 and 26 during observations made with the meridian circle."

Although Gould's period is somewhat in error, yet he recognised the peculiar nature of the star's variation.

R Centauri has been under observation at Lovedale since 1891, and during that time six principal and five secondary maxima have been determined.

Several secondary maxima have also been observed. The principal minima, however, as they fall as low as the 13th magnitude, are beyond the reach of the telescopes at my disposal, and so the dates of this phase have been obtained by estimation only from examination of the light curve.

The magnitudes at principal maxima, while on the average $0^{m}\cdot4$ brighter than the average of secondary maxima magnitudes, are singly sometimes fainter than the preceding maximum.

Thus the secondary maximum of 1900 April 5 is $6^{m}\cdot1$, but the following primary maximum of 1900 November 12 is only $6^{m}\cdot4$.

The dates of principal maxima observed either at Cordoba or at Lovedale are as follows :—

		Mag.	Res.
Cordoba	1871 April 15	6·1	+11^d
"	1872 Sept. 30	6·0	−25
"	1877 Aug. 3	>6·4	+33
Lovedale	1891 July 10	6·6	+ 5
"	1893 Jan. 10	5·3	−13
"	1894 Aug. 15	6·0	+ 2
"	1896 Mar. 12	5·8	+ 7
"	1899 April 15	5·7	− 1
"	1900 Nov. 12	6·4	+ 6

These dates yield a period of

568·5 days,

and for the epoch of principal maxima

1900 November 6.

The dates of secondary maxima are :—

		Mag.	Res.
Cordoba	1872 April 20	6·7	+ 2^d
"	1878 June 28	6·1	−10
Lovedale	1892 June 11	6·0	−25
"	1894 Feb. 10	6·6	+24
"	1895 Sept. 2	6·5	+17
"	1898 Sept. 27	6·5	+ 2
"	1900 April 5	6·1	−11

These yield a period of

568·0 days,

and for the period of secondary maxima

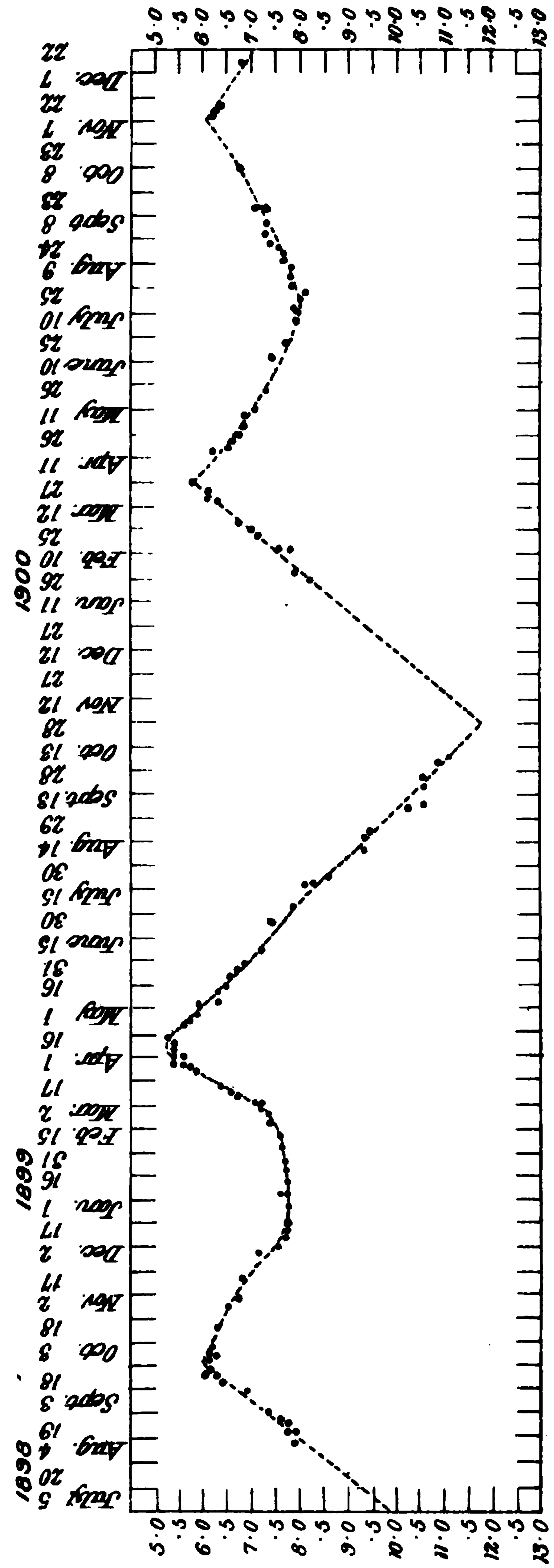
1900 April 16.'

The residuals between the observed and computed dates are given in the last column of both tables. It will be evident that they are not excessive, considering the duration of a full cycle of variation.

A secondary minimum ($8^m·7$) was observed by Gould 1872 August 3. The last secondary minimum observed at Lovedale was 1900 July 28 ($8^m·4$).

A comparison of these two dates yields a period of

567·8 days.



Light Curve of R Centauri (Gn. 5096), 1898, 1899, 1900.

The full period of *R Centauri* may, therefore, be thus determined :—

From principal maxima,	568·5,	weight 3
secondary maxima,	568·0,	weight 2
secondary minima,	567·8,	weight 1
Mean period ...	568·2	

The full elements of the star's variation may be thus tabulated :—

Period	$568^{d}·2$
Chief minimum	*J.D.* 1,414,964
Secondary maximum	5126
Secondary minimum	5228
Principal maximum	1,415,330

The two maxima follow one another at intervals of 204 and 364 days respectively, instead of 197 and 378, as Dr. Gould has it.

The period found by Dr. Gould, 525 days, is evidently due to a slip in addition, as the two combined intervals give 575 days.

Both from the Cordoba observations and the Lovedale observations there is evidence that the star at its lowest minimum sometimes reaches the 13th magnitude. To exemplify as clearly as possible the nature of the variation of *R Centauri*, the observations made at Lovedale in the years 1898–1900 have been charted down in Plate 10. During this period two full cycles have been nearly completed, and the general type of the variation can be readily seen from an examination of the light curves. In the 1898–99 period the principal maximum is distinctly brighter than the secondary maximum. The form of the light curve also between the two maxima is somewhat irregular. In the 1899–1900 observations the principal and secondary maxima are practically equal, and the form of the light curve is very regular.

The rise either to principal or secondary maximum is not markedly more rapid than the descending rate. While a rapid ascent to maximum is a characteristic of all short-period variables, it is by no means a general rule with regard to long-period variation. Indeed, there are instances where an opposite law—a more rapid decline to a minimum—seems to govern the variation of the star's light.

On the Observation of Position Angles of Polar Double Stars. By R. T. A. Innes.

The coordinates of an equatorial telescope do not, in general, coincide with those of the sky. Error is thus introduced into measures of position angle determined with the micrometer adjusted to the instrument. This question has been considered by Chauvenet (vol. ii. pp. 393, 394), but the formula he arrives at is not adapted for use in practice. In the case of stars some distance from the pole the instrumental errors are wholly eliminated by allowing the stars to travel along the wire by diurnal motion, and so refer the zero of the position circle to the sky itself. This method was even adopted in the case of *Polaris* by Otto Struve (Pulkowa Observations, vol. ix. p. 10). Experiments show that this is a very tedious method in the case of polar stars, and one requiring repeated observations to secure accuracy. The following method is both extremely simple and accurate :—

Set on the polar star to be measured; find the instrumental zero of the micrometer position circle by moving the telescope in declination by the slow-motion handle; then determine the star's position angle and add to it the instrumental hour angle less the real hour angle (in arc).

The rationale is as follows :—

Adopting as far as possible Chauvenet's notation (vol. ii. p. 375) we have

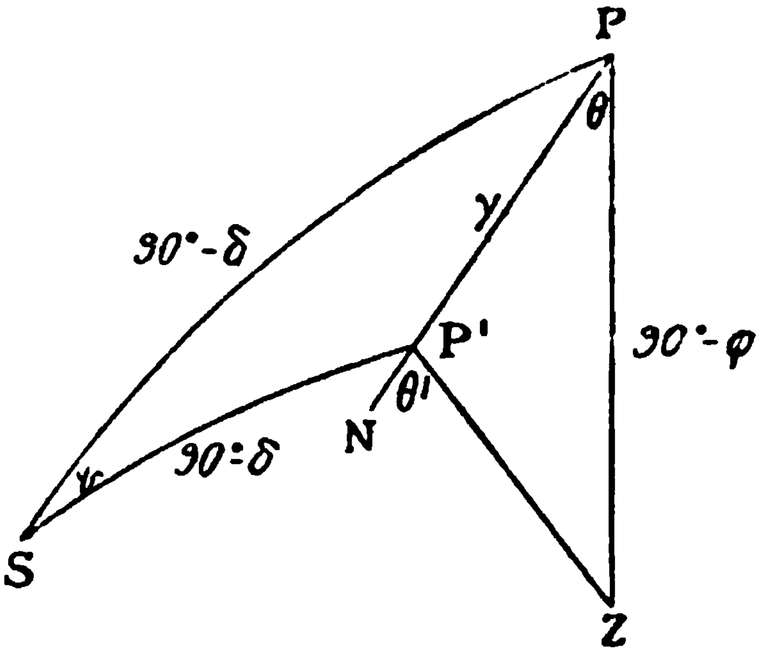


FIG. 1.

P = pole of sky
S = star
ZPS = τ = hour angle of star
PS = $90° - \delta$ = polar distance of star
ZPP' = θ
PP' = γ
PZ = $90° - \phi$ = colatitude
P'PS = $\tau - \theta$
Po = observed position angle

P' = pole of instrument
Z = zenith
ZP'S = t' = instrumental h. angle of star
P'S = $90° - \delta'$ = instrumental p.d. of star
ZP'N = θ'
PSP' = q
ϵ = spherical excess of the triangle PSP'
PP'S = $180° - \text{SP'N} = 180° - (t' - \theta')$
p = true position angle = $P_o + q$

The sum of the three angles of PP′S gives

$$q+r-\theta+180^\circ-t'+\theta'=180^\circ+\epsilon$$

whence

$$q=t'-r+\theta-\theta'+\epsilon$$

or putting

$$t'-r=\Delta a$$

$$q=\Delta a+\theta-\theta'+\epsilon \quad \dots \quad \dots \quad \dots \quad \text{(A)}$$

Chauvenet (vol. ii. p. 378) shows that, when the instrument is so adjusted that cos γ can be assumed equal to unity, we have

$$\theta-\theta'=\gamma \sin \theta \tan \phi.$$

In a fairly adjusted instrument $\gamma \sin \theta$ should be under $2'$, so that $\theta-\theta'$ is negligible. Still, should $\theta-\theta'$, which is a constant for all stars, be thought of importance, it can be computed very easily.

To evaluate ϵ we have

$$\sin \tfrac{1}{2}\epsilon=\frac{\sin q \sin \frac{1}{2}(90^\circ-\delta) \sin \frac{1}{2}(90^\circ-\delta')}{\cos \gamma}$$

and giving $\sin q$ a maximum value of unity, and taking $\cos \gamma=1$ we have

δ or δ'	ϵ
80°	52′
85°	12′
88°	2′
88° 50′	0′·6

Therefore for polar stars the equation (A) can be written

$$q=\Delta a.$$

In Chauvenet's method there still remain the corrections due to error in the adjustment of the telescope with reference to its own axes. Chauvenet (vol. ii. p. 393) calls these Q, where

$$Q=90^\circ-QSP'$$

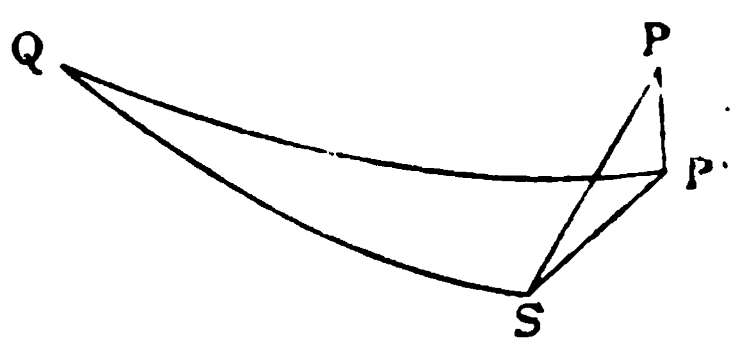


Fig. 2.

and assumes that the zero of the position circle is perpendicular

to QS. But, as Mr. S. S. Hough has kindly pointed out to me, the zero should be found as previously indicated by setting on the polar star to be measured, and whilst the clock is driving the instrument, moving the telescope in declination until the star keeps on the wire. The zero found in this manner is freed from all errors due to instrumental causes having tan δ or sec δ as a factor, and the necessity to compute Q is evaded.

With instruments such as the McClean and 7-inch refractors of this observatory, where the hour circles show right ascensions direct, the difference between the instrumental R.A. and the star's R.A. gives $15 \Delta a$ at once.

This method gains in accuracy as the star is nearer the pole. It is easily seen that it is applicable even if the star is situated between the pole of the sky and the pole of the instrument. All but the very minute differential effect of flexure is eliminated.

Finally, by using the above method for polar stars and the diurnal motion method for other stars, it is apparent that in neither case is a knowledge of the instrumental constants necessary in the measurement of double stars.

Royal Observatory, Cape of Good Hope:
1901 *January* 11.

Further Corrections to the Armagh Catalogue, with Special Reference to the "Anonymous" Stars. By J. L. E. Dreyer, Ph.D.

Shortly after I had communicated to the Society the list of corrections which appeared in the *Monthly Notices* for November (p. 10), Dr. Ristenpart, who is engaged in the preparation of a general catalogue of stars, kindly sent me a list of Corrigenda, chiefly referring to wrong degrees or minutes and similar errors. At the same time he requested me to examine the original records in order to solve a number of questions, chiefly concerning the identity of the "anonymous" stars in the Armagh Catalogue. I gladly complied with this request, as the publication of the invaluable star catalogues of the *Astronomische Gesellschaft* has now made it possible to decide many cases of doubtful identity which formerly could only have been cleared up by new observations. Some of the suggestions made by Dr. Ristenpart turned out to be correct, or at least to be very plausible; but frequently the examination of the original observations revealed very curious errors, which could never have been suspected by anyone who had not access to the originals. Many of these errors were caused by the fact that the R.A. and P.D. were observed with different instruments, and most of them could have been avoided by greater care on the part of the observers in describing the star observed and others near it, as well as in recording degrees and minutes.

In a number of cases it is necessary to assume that the observer with the transit instrument has set on a star of south instead of north declination, and *vice versa*. Up to 1844 the setting was made by either of two 6-inch setting circles at the eye end of the transit instrument, one giving altitudes, the other zenith distances, but as the working lists have not been preserved, I am unable to say whether these gave altitude (or Z.D.), or whether the observer had perhaps to find this mentally from the Decl. or P.D. of the star, though this is hardly likely to have been the case. As there is no clamp, the instrument may sometimes have been slightly displaced without the observer's knowledge, and a wrong star may have been observed in consequence.

When corrected for the errors given in the following pages, the Armagh Catalogue ought to be free from all gross errors, with the exception of one or two cases, in which I was unable to find a plausible correction.

The references Berlin, Leipzig, Harvard, &c. are to the A.G. Zone Catalogues.

94. Minutes of P.D. are 58′ (error of reduction).

118. R.A. belongs to $+14^\circ{\cdot}78$ (P.D. 75° 34′). The P.D. corrected by $-1'$ (error of obs.) is that of $+14^\circ{\cdot}89$, R.A. being $0^h\ 32^m\ 12^s$.

176 and 177 P.D. is 63°.

192. Error of reduction. R.A. should be for 1845·0 $0^h\ 46^m\ 57^s{\cdot}83$. It is probably $=+23^\circ{\cdot}126$, the observer having set 1° wrong. If so we have for 1840 $0^h\ 46^m\ 41^s{\cdot}88$ (P.D. 66° 19′) in good accordance with Berlin B. 285.

234. Minutes of P.D. must be 33 instead of 29 (Schj. 367). No minute in original obs.

272. P.D. is 17°.

302 = 303. In the latter there is an error of reduction; the seconds should be $27''{\cdot}53$.

314. P.D. is 46°.

321 is marked "Comet star *e*." No magn. in original obs. except on November 23, 1845: "Very faint, $a = 1^h\ 19^m$." Error of reduction, R.A. should be $1^h\ 20^m\ 12^s{\cdot}63$, and the minute ought to be 19, as the star is B.W. $1^h{\cdot}333$ = Gött. 312.

469. Seconds of R.A. should be $24^s{\cdot}25$, error of reduction.

476. Seconds of P.D. should be $14''{\cdot}52$ (assumed place wrong).

492. Dr. Ristenpart suggests that if the P.D. is assumed to be 59° 30′ instead of 56° 30′± the star is $+30^\circ{\cdot}358$ = Leiden 836. If so, the R.A. would become $2^h\ 6^m\ 47^s{\cdot}28$ or $0^s{\cdot}67$ less than Leiden, so that the identity is doubtful. Reductions correct.

515. Minutes of R.A. are 14.

610. Minutes of R.A. are 39.

623. Minutes of R.A. are 47.

659. Prec. in R.A. is $3^s{\cdot}469$, misprint.

819. Seconds of P.D. should be $18''{\cdot}37$. All the corrections are $10''{\cdot}56$ too great.

873. R.A. (4^h 0^m $16^s{\cdot}68$, see errata) belongs to $+54°{\cdot}745$ (P.D. = 36° 1′). N.P.D. if corrected by +10′ is that of No. 877. No error of reduction.

898. Observed 1849 February 13 (not January), $3^s{\cdot}26$ following 50 *Tauri*, therefore α is $20^s{\cdot}00$ too small, and $* = +20°{\cdot}725$.

899. Error of reduction in α; it should be 4^h 7^m $39^s{\cdot}69$ = No. 900 = G. 806. In P.D. the observer has altered the observed minute from 37 to 38, but if we reject this correction we get 29° 39′ 18″·1 in excellent accordance with G. 808 and Radcl. 1189 (R.A. = 4^h 7^m 55^s).

922. P.D. minute should be 35.

1087. Prec. in R.A. should be $8^s{\cdot}299$ (used in reductions).

1140. R.A. is $1^s{\cdot}00$ too great (error of reduction).

1170. Seconds of P.D. should be 48″·63 (error in assumed place).

1202. Prec. in R.A. is $3^s{\cdot}394$, also an error of 1^s in the reduction, so that R.A. becomes 5^h 20^m $26^s{\cdot}08$ (P.D. = 88° 55′). Star is B.W. $5^h{\cdot}508$.

1257. The R.A. is given for 1850. For 1840 it becomes 5^h 29^m $16^s{\cdot}90$. Star is $+7°{\cdot}952$.

1266. Minutes of R.A. are 30.

1296. Prec. in R.A. is $3^s{\cdot}429$ (used).

1343. There are here two stars nearly on the same parallel, $\Delta\alpha = 23^s$. Doubtless the P.D. belongs to the preceding one, $+24°{\cdot}1039$ = Berlin B. 2074, which is for 1840 65° 24′ 53″·3. R.A. = 5^h 47^m 48^s.

1438. P.D. should be 37″·93 (error in changing "assumed place" from *Naut. Alm.* to A.S.C.).

1439. Observer has given α as 6^h 17^m. I cannot find why the star was observed, nor why α was altered. It is therefore = $+13°{\cdot}1250$ = Leipz. 2260. With correct precession we get 76° 48′ 30″·58, $\alpha = 6^h$ 17^m 38^s.

1450. P.D. should be 18″·71 (error of reduction).

1451. R.A. is 6^h 18^m $13^s\pm$.

1454. The minute observed is 16 (not 17), but it ought to be 15, as the star must be = $+0°{\cdot}1405$, P.D. being 89° 36′.

1490. Probably = 1491. Observed for a "Halley's comet star" with the note "not the star." With the constants and precession of 1491 the R.A. becomes 6^h 24^m $40^s{\cdot}12$.

1494. The only star with this P.D. is $+33°{\cdot}1328$ = B.W. $6^h{\cdot}517$, the R.A. of which is 6^h 17^m 41^s. The seconds of P.D. would be 17″·77. Also observed for a comet star.

1498. Prec. in R.A. is $3^s{\cdot}915$.

1503. R.A. of this and P.D. of 1509 belong together, = $+33°{\cdot}1371$, while the R.A. of 1509 belongs to $+34°{\cdot}1416$, P.D. 55° 34′.

1559. R.A. belongs to $+8°{\cdot}1543$ = Leipzig II. 3300, P.D. = 81° 26′.

1561. The R.A. of this and the P.D. of 1559 form $+8°{\cdot}1544$ = Leipzig II. 3303.

1594. Seconds of P.D. should be $37''\cdot75$ (error of reduction).

1620. Dr. Ristenpart suggests that if corrected by -1^{m} this would be $= +15^{\circ}\cdot1482 =$ Berlin A. 2643 (P.D. 74° 19′). No error of reduction, observed for 45 *Geminorum*.

1628 is $+15^{\circ}\cdot1496 =$ Berlin A. 2675, P.D. 74° 34′.

1630 is $+15^{\circ}\cdot1497 =$ Berlin A. 2679. P.D. 74° 34′.

1655 P.D. degrees are 86° (misprint).

1839 Prec. in R.A. is $4^{s}\cdot677$ (misprint).

1855 Minutes of R.A. are 11.

$\left.\begin{array}{l}1911\\1912\end{array}\right\}$ Seconds of R.A. are 44 and 46; corrections to P.D. for precession are respectively $-0''\cdot53$ and $-0''\cdot61$.

1917. The P.D. must belong to 41 *Cancri*, as P. 128 (observed with micrometer) is said to precede it.

1920. P.D. $-1'$ makes the star $= 1925$. This error of observation equally affects 1922 (the $\Delta\delta$ of which from 1920 was measured by the micrometer) which then is $= 1923$.

1921. $\Delta\delta$ measured from 42 *Cancri*; observer adds "north of two preceding." So it must be $+20^{\circ}\cdot2165 =$ Berlin B. 3489.

1937. Observed with the micrometer as a comes to δ *Cancri*, but it is not stated whether it is p or f. ΔN.P.D. $= +22''\cdot2$, but there must be some error of observation, as the star can only have been No. 1931, which then was 65″ south of δ *Cancri*. No plausible correction to the recorded measure will, however, change 22″ into 65″.

1946. Minute of P.D. is 1′.

1965. The first two observations give the minute of P.D. as 19 and 29, while the third gives neither degree nor minute. It was observed for 52 *Cancri*, and must be either this star (73° 24′) or $+16^{\circ}\cdot1834$ (73° 14′).

2002. Probably $= 2001$ with an error of 5′. If so, seconds become $23''\cdot89$.

2041 is $= 2040$ with an error of 1′.

2060. Dr. Ristenpart proposes to read 103° 3′± for 103° 54′±, the star being $-13^{\circ}\cdot2825$. The observer set for P. 39.

2162. Observed over six wires. Is it $= 2160$ with an error of 20 in counting the seconds? Dr. Robinson remarked afterwards that there is no star in the place of 2162.

$2238 = +83^{\circ}\cdot296$. I cannot make out how the places given in the Catalogue were found. Δa from P. X. 22:—

Apparent	$-46^{s}\cdot17$	mean	$-46^{s}\cdot18$
	46·33		46·34
	45·67		45·38
	46·13		46·14

Place for 1840: $10^{h}\ 10^{m}\ 8^{s}\cdot26$, 6° 31′·3.

2281. The observer set for 31 *Sextantis*. He notes: "Double, the large taken" (*i.e.* the sf one by a diagram). The star is

therefore ♉ 1440, and he must have set for $-3°$ instead of $+3°$. P.D. 93° 5′.

2307 is = 2308, Groombridge being 30^s wrong.

2319 = Schj. 3899, R.A. = $10^h\ 31^m\ 49^s$.

2355. The R.A. is that of $+70°{\cdot}635$ = A.Ö. 11184, the P.D. of which is 19° 16′·0, while the P.D. is that of $+70°{\cdot}625$ = A.Ö. 11109, the R.A. of which is $10^h\ 36^m\ 56^s$.

2357. Minutes of P.D. are 38′.

2395. The observer believed he had set for P.X. 221 and put down the P.D. of that star; but he must have set for 90° 41′ instead of 89° 14′±, as the R.A. observed is that of Gött. 3585.

2398. P.D. should be 90° 42′, Gött. 3589. Note to this and 2395 in Second Armagh Catalogue to be cancelled.

2479 = 2478.

2520. R.A. is wrong. It precedes 92 *Leonis* $1^m\ 16^s{\cdot}42$ and is = $+22°{\cdot}2387$ = Berlin B. 4323. $11^h\ 31^m\ 11^s{\cdot}15$, 67° 48′±.

2584. The observer remarks 1844 Apr. 16: "The large ✱ following is also bisected." This large star must have been 67 *Ursæ*, which has a P.M. of $+0''{\cdot}060$ in P.D. and in 1844 was exactly on the parallel of $+43°{\cdot}2177$ = Bonn 8308. Therefore this was the star observed with an error of 5′, which error must also have been made in 1854, though perhaps it was 67 *Ursæ* which was observed 1854 April 1. The R.A. of 2584 is $11^h\ 53^m\ 19^s$, P.D. 46° 3′ 58″.

2607. Dr. Ristenpart suggests that the observer set for $-6°$ 53′± instead of for $+6°$ and that the star is B.W. $12^h{\cdot}27$ = Schj. 4390. Observed instead of 11 *Virginis*.

2611. Minute of R.A. should be 2^m, no minute in original observations (= Radcliffe 2803).

2674. Observed instead of 2676. The R.A. of $+37°{\cdot}2278$ in the Lund zones agrees well, but the P.D. of this star for 1840 is 52° 45′, so that even an error of 10° in setting would leave 26′ not accounted for. An error of 1° would bring us to Cambridge 6122 (64° 11′) but this differs more than a second in R.A.

2711. Seconds of P.D. are 27″·34, error of reduction.

2807. Seconds of R.A. should be $29^s{\cdot}68$, P.D. 61″·31. Star is $+28°{\cdot}2185$ = Cambridge 6356 = Armagh 2805.

2815. P.D. must be 99° 57′ as B.W. $13^h{\cdot}22$ seems the only star possible.

2909. Minutes of P.D. are 33′, error of reduction.

3025. Minute of P.D. must be 17′ according to Berlin A. 5159.

3042. I cannot identify this star; reductions correct, except that the first R.A. should be $33^s{\cdot}24$. Observed for P. xiv. 52.

3075. Dr. Ristenpart suggests that the instrument was set to P.D. 40° 30′ instead of 39° 30′, and that the star is $+49°{\cdot}2305$.

3095. Minutes of P.D. are 53 (misprint).

3137. P.D. is 57° 19′ 47″·70, R.A. = $14^h\ 47^m\ 39^s$. The "corrections" must have been applied to a wrong "assumed place" when making up the final catalogue.

3178. Minutes of P.D. are 37′, error of observation.

3212. Seconds of R.A. are $38^s{\cdot}61$, error of reduction.

3425. Prec. in P.D. is $8''{\cdot}134$.

3444. Correction should be $-6''{\cdot}99$ and seconds of P.D. $42''{\cdot}42$.

3461. Minutes of P.D. are 28.

3544. P.D. is 91° 20′ $11''{\cdot}31$; the minute only noted once, and there is an error in the reduction to 1840.

3600. On p. 767 the figure 1 has dropped out ($41''{\cdot}87$).

3651. Observed for 6 *Sagitt.*, there seems no star possible except $-15^\circ{\cdot}4767$, P.D. 105° 48′.

3674. Minutes of R.A. are 54.

3714. P.D. is 77°; corrections $+4''{\cdot}43$ and $+3''{\cdot}13$. Seconds $2''{\cdot}74$.

3721. Dr. Ristenpart suggests that the instrument was set to 39° instead of 33°, in which case the star would be $+50^\circ{\cdot}2549$ = Harvard 5526, P.D. 39° 5′. The conjecture is probably right, and the R.A. would then be $18^h\ 11^m\ 30^s{\cdot}95$.

3729 = 3727 = L.L. 33792, Baily's R.A. being 28^s out.

3745 would seem to be Schj. 6710, P.D. 92° 32′.

3758 Minutes of P.D. are 51′.

3777. Dr. Ristenpart suggests that this is $+22^\circ{\cdot}3385$ = Berlin B. 6500, P.D. 67° 20′.

3835. Minutes of R.A. are 36 = 3831, error of reduction.

3844. Minute of R.A. must be 41. Schj. 6969.

3902. Dr. Ristenpart thinks that this is Schj. 7054, P.D. 90° 40′ instead of 87° 40′. The error must have been in the working list, as the same wrong setting was made on two nights. Observed for 64 *Serpentis.*

3908. To be struck out. Simply a repetition of 3909.

3940. Degrees of P.D. are 61°, not 16. In original "$21^s{\cdot}5$ p. P. 318."

3970. P.D. is 63° $25'{\cdot}4$.

3980. Dr. Ristenpart suggests that the P.D. was 84° 15′ instead of 94° 15′, which would alter the seconds of R.A. to $55^s{\cdot}34$ and make the star = Leipzig. II. 9118.

3982. Minutes of R.A. are 9^m, $= -1^\circ{\cdot}3701$; clerical error.

3985. P.D. must be 70° 2′ ±, seconds of R.A. $5^s{\cdot}09$.

4003. There is an error of 1^m in the first observation; single results are $28^s{\cdot}45$ and $28^s{\cdot}27$. R.A. = $19^h\ 9^m\ 28^s{\cdot}36$ P.D. 24° 10′.

4043. P.D. is 105° 30′.

4088. Is a "comes preceding" to 10 *Cygni*, $\Delta\delta$ measured 1′ $26''{\cdot}53$, not stated whether north or south. It must be $+51^\circ{\cdot}2157$, south of 10 *Cygni.* $19^h\ 24^m\ 29^s$, 38° 37′ $55''{\cdot}03$ in good agreement with Harvard 6035.

4100. Seconds of R.A. are 24. Munich_2 8938.

4110. Dr. Ristenpart suggests that it is $-2^\circ{\cdot}5057$, P.D. 92° 40′. Observed for P. xix. 183.

4163. Prec. in R.A. is $2^s{\cdot}824$, misprint. P.D. 78° 28′.

4210 is G. 2978, and has been reduced on that supposition. By obs. it is $2^m\ 13^s\cdot33$ p. G. 2991, which gives $19^h\ 49^m\ 58^s\cdot12$, which is $4^s\cdot0$ less than Radcliffe 4509. There must be an error in counting the seconds. Only three wires observed, which agree very badly.

4221. This star was observed in the usual way and G. 2984 was by micrometer found to be $48''\cdot37$ south of it. There is an error of reduction, P.D. should be $50°\ 2'\ 41''\cdot10$. It seems to be $= +39°\cdot3966$, though this star is only of 9·2 mag.

4226. In the original note-book this is described as "G. 3057 (o. ed.)," with another 5^s following. This means that the observer set for No. 3057 of the suppressed edition of Groombridge's catalogue* or G. 2988 = Radcliffe 4524, and the wire transits have indeed been reduced with $\delta = 43°\ 50'$. A sketch made agrees with the relative positions of $+43°\cdot3422-23-25$. For some unknown reason the two stars observed were afterwards taken to be an anonyma and P. xix. 354 in P.D. 52° ! Properly reduced we get for 1840

	h	m	s	°	′	
4226	19	51	40·39	46	9	Epoch 1842·638.
4228*a*		51	45·67	46	5	

4228. The first result in R.A. to be struck out, seconds $=45^s\cdot20$, epoch 1850·997.

4230 follows 10^s after 4228, and is therefore $= +38°\cdot3836$. For 1840

$$19^h\ 51^m\ 55^s\cdot31 \quad 52°\ 1'.$$

4231 = 4230 = L.L. 38172 = 4233.

4360. For 1844 October 28 read August 28.

4361. Observed $1^s\cdot28$ p 4360, therefore $= +9°\cdot4507$ = B.W. $20^h\cdot400$.

$$20^h\ 15^m\ 44^s\cdot95 \quad 80°\ 6'.$$

4388. Two different stars. Minutes of R.A. should be 20 (obvious error of obs.), and its P.D. is $60°\ 9'\cdot3$ $(= +29°\cdot4038)$. The R.A. of the star observed in P.D. is $20^h\ 22^m\ 39^s$ $(= +29°\cdot4055)$.

4421. The R.A. is that of $+34°\cdot4082$, P.D. $55°\ 12'$, but the star observed in P.D. was $1'\ 56''\cdot16$ south of 47 *Cygni* and is described as "very faint companion." It must have been $+34°\cdot4076$, 9·5 mag., 16^s p, $1'\cdot3$ south, R.A. $= 20^h\ 27^m\ 24^s$.

4579 and 4580. "Two of same R.A.," therefore $= +55°\cdot2529-30$, R.A. $= 21^h\ 3^m\ 51^s$ and 52^s.

4593. Minutes of P.D. are 27. Prec. in R.A. is $1^s\cdot508$ (misprint).

4636. Dr. Ristenpart suggests that the P.D. was $71°\ 36'$ and the star $= +18°\cdot4772$.

* About this see p. v of the published Catalogue. There is a copy of it in the library of Armagh Observatory.

4641. Degrees of P.D. are 100 (misprint).

4645. Must be $= +36^\circ{\cdot}4522$, R.A. $21^h\ 14^m\ 6^s$, seconds $18''{\cdot}90$.

4646. Must be $= +36^\circ{\cdot}4534$, R.A. $21^h\ 15^m\ 58^s$, seconds $25''{\cdot}28$.

4673. Minutes of P.D. are 17.

4678=P. xxi. 158=B.A.C. 7473. Minutes should be 22^m, error of obs.

4790. Measured by micrometer $+1'\ 43''{\cdot}30$ from 4789, is therefore south of the latter. The observer at first thought he had observed 4785 (no degrees or minutes recorded !) and a comes, hence the erroneous position of 4790. It is

$$+53^\circ{\cdot}2741,\ 21^h\ 49^m\ 42^s,\ 36^\circ\ 51'\ 8''{\cdot}27.$$

4793. I cannot explain how the P.D. $16^\circ\ 54' \pm$ was made out, as the wire transits have been reduced with P.D. $18^\circ\ 45'$, and thus the five wires observed agree very well indeed. The constants of 79 *Draconis* (or a star near it) were used, and an error of 1^s was made. In the original the minute observed is recorded as 50 with a 1 written over the 0, and the 0 has been adopted, which happens to be wrong. It is $+71^\circ{\cdot}1097$=Radcliffe 5473, and reduced anew it becomes $21^h\ 50^m\ 41^s{\cdot}12$ (Prec. $+0^s{\cdot}966$), $18^\circ\ 46'$. [illegible]

4798. Must be $-13^\circ{\cdot}6072$, R.A. $21^h\ 52^m\ 15^s$ (9·2 mag.).

4808. If minutes of R.A. are taken as 52 instead of 53, the R.A. agrees with that of Leipzig II. $11065 = +7^\circ{\cdot}4777$, P.D. $82^\circ\ 54'$. Observed for 19 *Pegasi*.

4810. Minutes of P.D. are 42 (misprint).

4830. R.A. is $22^h\ 0^m\ 20^s$ $(= +62^\circ{\cdot}2030)$.

4845. Dr. Ristenpart suggests that the P.D. was $95^\circ\ 43'$ instead of $94^\circ\ 40' \pm$, as the star must have been B.W. $22^h{\cdot}29$ $= -5^\circ{\cdot}5720$.

4855.
4858. } The first is Bradley 2935=G. 3707, the second is G. 3709. On 1844 October 10 the observer says "the preceding star," but a diagram shows the following star bisected on the horizontal wire. On 1850 November 27 he adds "took the brightest." The preceding star is the brightest, and, no doubt, it was observed on the other occasions when no note was made. The P.D.'s of 4855 and 4858 are therefore to be interchanged, after which they will be in excellent accordance with Radcliffe, Greenwich, and Σ 2873.

4918. P.D. should be $48^\circ\ 44'\ 53''{\cdot}44$.

4960. Must be $= +12^\circ{\cdot}4843$, P.D. $77^\circ\ 25'$.

4964=4966=L.L. 44154.

4968=4969.

4971. Stated by observer to follow 4960, therefore $= +12^\circ{\cdot}4849$, P.D. $77^\circ\ 21'$.

5080. See p. 613. I cannot identify this star : it was measured by micrometer $+3'\ 37''{\cdot}21$ (south) from 1 Andromedæ. It is called a "comes," but as usual there is not a word about the magnitude nor about the difference of R.A. $+41^\circ{\cdot}4660$ (9·4 mag.) is $1^m\ 40^s$ p 1 Androm., $3'{\cdot}5$ *north*.

5114. Must be several minutes preceding B. 3077, as it was observed in the usual way with four microscopes before B. 3077 came into the field. It is therefore $= +56^{\circ}\cdot2952$, R.A. $23^{h}\ 1^{m}\ 30^{s}$. How the R.A. of this and other anonymous stars came to be given to a second in the Catalogue, though only given roughly to the nearest minute in the "observed places," is altogether a mystery.

5141. Must be G. 4025, which is $1^{m}\ 45^{s}$ p and $1'\ 50''$ north of G. 4029. The former was observed on the fixed wire with four microscopes, and the latter was measured with the micrometer, $\Delta\delta = 1'\ 16''\cdot97$. I can only suppose that the instrument was accidentally displaced after setting on the first star and before setting on the second star. This would explain why the place of the first star is wrong, while that of the second is right.

5177. Measured from 4 *Cassiopeiæ*, minutes of P.D. should be 36. On November 17 it is called "preceding, 9 mag.," on November 20 only "comes." $+61^{\circ}\cdot2448$ is the only star, but it *follows* 4 *Cassiopeiæ* 58^{s}, $1'\cdot2$ south, R.A. being $23^{h}\ 18^{m}\ 44^{s}$.

5190. Observed with 5193, "preceding, exactly bisected, 7 mag." No $\Delta\alpha$ given. Not mentioned on the other nights when 5193 was observed, and looked for in vain in 1859 and 1865. It must have been a minor planet, the magnitude may have been exaggerated.

5295. Minutes of P.D. are 19, error of reduction, R.A. $= 23^{h}\ 49^{m}\ 50^{s}$.

5322. Minutes of R.A. are 54, it follows $2^{s}\cdot49$ after B. 3202.

5338. Degrees of P.D. are 86.

$\left.\begin{matrix}5339\\5340\end{matrix}\right\}$ Are mere repetitions of 4154 and 4357.

Finally, in the Appendix, p. 828, β *Cassiopeiæ*, the minutes of P.D. should be 43.

Note on Mr. Bryan Cookson's Paper, "On the Accuracy of Eye Observations of Meteors and the Determination of their Radiant Points." By H. C. Plummer, M.A.

1. Mr. Cookson's paper must be regarded as a welcome and valuable attempt to deal with a question of great importance and interest. It is the more necessary, therefore, to point out an error which occurs in his theory. The correction is offered here with no idea of detracting from the merit of the author's contribution, and it is believed that his oversight in no way affects the validity of his general conclusions.

2. The error occurs in the expression which Mr. Cookson obtains for the weight of an equation. The result ought to be simplified by the suppression of the Q term. It seems clear on general grounds that the weight ought to be independent of the

directions of the axes, and it was this consideration which led me to suspect the accuracy of the expression. I am not concerned to criticise Mr. Cookson's assumptions as to the nature of the probable errors of the recorded observations. I admit, moreover, the principle according to which mean errors are obtained from a linear differential relation, though it must be borne in mind that this goes deeper than the assumption of a definite form of probability function. For since higher powers of the errors are neglected in comparison with the first in the differential relation, fourth and higher powers can be neglected in the probability function.* The clearest, if not perhaps the shortest, method of treating the question is to express p directly in terms of the observed quantities.

3. I retain as far as possible Mr. Cookson's notation. Let b_1, b_2 be the extremities of the projection of the meteor's path, and let $Ob_1b_2=\psi_1$, $Ob_2b_1=\psi_2$. Now

$$\delta p=\frac{\partial p}{\partial r_1}\cdot\delta r_1+\frac{\partial p}{\partial\theta_1}\cdot\delta\theta_1+\frac{\partial p}{\partial r_2}\cdot\delta r_2+\frac{\partial p}{\partial\theta_2}\cdot\delta\theta_2.$$

By assumption dr_1, $\sin r_1\,d\theta_1$, dr_2, $\sin r_2 d\theta_2$ are displacements in the sense of which errors are independent and equally likely to the same amount. Hence

$$\epsilon_p{}^2=\frac{\epsilon^2}{2}\left\{\left(\frac{\partial p}{\partial r_1}\right)^2+\left(\frac{1}{\sin r_1}\cdot\frac{\partial p}{\partial\theta_1}\right)^2+\left(\frac{\partial p}{\partial r_2}\right)^2+\left(\frac{1}{\sin r_2}\cdot\frac{\partial p}{\partial\theta_2}\right)^2\right\}.$$

The polar coordinates of b_1, b_2 are $(\lambda\tan r_1, \theta_1)$ and $(\lambda\tan r_2, \theta_2)$, and therefore

$$p=\frac{\lambda\tan r_1\tan r_2\sin(\theta_2-\theta_1)}{\sqrt{\{\tan^2 r_1+\tan^2 r_2-2\tan r_1\tan r_2\cos(\theta_2-\theta_1)\}}}$$

$$\therefore\frac{1}{p}\cdot\frac{\partial p}{\partial r_1}=\frac{\sec^2 r_1}{\tan r_1}-\frac{\tan r_1-\tan r_2\cos(\theta_2-\theta_1)}{\tan^2 r_1+\tan^2 r_2-2\tan r_1\tan r_2\cos(\theta_2-\theta_1)}\sec^2 r_1$$

$$=\frac{\sec^2 r_1\,.\,\tan r_2\{\tan r_2-\tan r_1\cos(\theta_2-\theta_1)\}}{\tan r_1\,.\,D^2/\lambda^2}$$

$$=\frac{\lambda^2+\rho_1{}^2}{D^2}\cdot\frac{\rho_2}{\rho_1}\cdot\frac{\rho_2-\rho_1\cos(\theta_2-\theta_1)}{\lambda}$$

$$=\frac{\lambda^2+\rho_1{}^2}{D^2}\cdot\frac{\rho_2}{\rho_1}\cdot\frac{D\cos\psi_2}{\lambda}$$

$$=\frac{(\lambda^2+\rho_1{}^2)\,.\,\sqrt{(\rho_2{}^2-p^2)}}{D\lambda\rho_1}$$

* Bertrand, *Calcul des Probabilités*, p. 267.

Also

$$\frac{1}{p}\cdot\frac{\partial p}{\partial\theta_1}=-\cot(\theta_2-\theta_1)+\frac{\tan r_1\tan r_2\sin(\theta_2-\theta_1)}{\tan^2 r_1+\tan^2 r_2-2\tan r_1\tan r_2\cos(\theta_2-\theta_1)}$$

$$=-\frac{\cos(\theta_2-\theta_1)(\tan^2 r_1+\tan^2 r_2)+\tan r_1\tan r_2(1+\cos^2\overline{\theta_2-\theta_1})}{\sin(\theta_2-\theta_1)\,.\,D^2/\lambda^2}$$

$$=\frac{(\tan r_1-\tan r_2\cos\overline{\theta_2-\theta_1})(\tan r_2-\tan r_1\cos\overline{\theta_2-\theta_1})}{\sin(\theta_2-\theta_1)\,.\,D^2/\lambda^2}$$

$$=\frac{\{2\rho_1^2-(\rho_1^2+\rho_2^2-D^2)\}\{2\rho_2^2-(\rho_1^2+\rho_2^2-D^2)\}}{4\lambda^2\rho_1\rho_2\,.\,\sin(\theta_2-\theta_1)\,.\,D^2/\lambda^2}$$

$$=(D^2+\rho_1^2-\rho_2^2)(D^2+\rho_2^2-\rho_1^2)/4pD^3$$

$$=\rho_1\rho_2\cos\psi_1\cos\psi_2/pD$$

$$\therefore\frac{\partial p}{\partial\theta_1}=\sqrt{(\rho_1^2-p^2)}\,.\,\sqrt{(\rho_2^2-p^2)}/D$$

Hence

$$\left(\frac{\partial p}{\partial r_1}\right)^2+\left(\frac{1}{\sin r_1}\cdot\frac{\partial p}{\partial\theta_1}\right)^2=\frac{(\lambda^2+\rho_1^2)^2(\rho_2^2-p^2)p^2}{D^2\lambda^2\rho_1^2}$$

$$+\frac{(\rho_1^2-p^2)(\rho_2^2-p^2)}{D^2}\cdot\frac{\lambda^2+\rho_1^2}{\rho_1^2}$$

$$=\frac{(\lambda^2+\rho_1^2)(\rho_2^2-p^2)}{D^2\lambda^2}(p^2+\lambda^2)$$

Similarly

$$\left(\frac{\partial p}{\partial r_2}\right)^2+\left(\frac{1}{\sin r_2}\cdot\frac{\partial p}{\partial\theta_1}\right)^2=\frac{(\lambda^2+\rho_2^2)(\rho_1^2-p^2)}{D^2\lambda^2}(p^2+\lambda^2)$$

$$\therefore\epsilon^2_p=\frac{\epsilon^2}{2}\cdot\frac{1}{\lambda^2D^2}(\lambda^2+p^2)\{(\lambda^2+\rho_1^2)(\rho_2^2-p^2)+(\lambda^2+\rho_2^2)(\rho_1^2-p^2)\}$$

$$=\frac{\epsilon^2}{2}\cdot\frac{1}{\lambda^2D^2}\cdot(\lambda^2+p^2)\,P$$

where P has precisely the same meaning as in Mr. Cookson's paper. Thus the formula for the weight of an equation is actually simplified to the extent of omitting the quantity Q.

4. It is now a matter of some interest to consider in what way Mr. Cookson's procedure is in fault. The forms found for ϵ_x and ϵ_y are right, but the author errs in applying them because the quantities x and y to which they refer are subject to errors which are not independent. That the contrary supposition is erroneous may be seen thus. The probabilities of errors ξ and η in x and y are proportional to exp. $(-\xi^2/2\epsilon_x^2)$, and exp. $(-\eta^2/2\epsilon_y^2)$. Therefore if such errors were independent, the probability of their concurrence would be proportional to exp. $(-\xi^2/2\epsilon_x^2-\eta^2/2\epsilon_y^2)$, and the locus

of equally likely resultant error would be $\xi^2/\epsilon_x^2+\eta^2/\epsilon_y^2=\text{const.}$, or an ellipse with axes parallel to the coordinate axes. But as a matter of fact this locus is the projection of a small circle on the sphere, and therefore an ellipse whose major axis passes through the origin. The locus on the sphere is given by $(\delta r)^2+\sin^2 r\,(\delta\theta)^2=\text{const.}$ Now since $r=\tan^{-1}\dfrac{\rho}{\lambda}$ and $\theta=\tan^{-1}\dfrac{y}{x}$ we have $\delta r=\dfrac{x\delta x+y\delta y}{\rho(\rho^2+\lambda^2)}\lambda$ and $\delta\theta=\dfrac{x\delta y-y\delta x}{\rho^2}$. Hence the locus of equal probability on the plane of projection is

$$\frac{(x\delta x+y\delta y)^2\lambda^2}{\rho^2(\rho^2+\lambda^2)^2}+\frac{(x\delta y-y\delta x)^2}{\rho^2(\rho^2+\lambda^2)}=\text{const.},$$

δx and δy being the current coordinates relative to (x, y) considered fixed. This reduces to

$$\frac{\xi^2}{\rho^2+\lambda^2}+\frac{\eta^2}{\lambda^2}=\text{const.}$$

when the axes are taken through (x, y), so that one, $\eta=0$, passes through the origin.

5. It may be useful to consider the question of independence in more general terms.* In ordinary mathematical operations it is possible to pass by processes of transformation from one set of quantities susceptible of variation to another set in such a way that the latter group contains the necessary elements of independence. Thus in general the same operations may be performed after the transformation as before. As regards the question in the theory of probability considered here, the same is not the case. In some instances the answer to the question is obvious; as, for example, when the number of quantities in the second set exceeds the number in the first (or at least generally in this case), or when the quantities of the second set can be expressed individually in terms of different members of the first set. It is when we have the same number of quantities in each set, as in the example discussed above, that the question is most interesting and most likely to be misunderstood.

6. Let $X_1, X_2 \ldots X_n$ be a set of quantities determined by direct observation, wholly independent and with mean errors denoted by $\epsilon(X_1) \ldots$ Suppose $Z=\phi(Y_1, Y_2 \ldots Y_m)$, where $Y_1=f_1(X_1, X_2 \ldots X_n)$, $Y_2=f_2 \ldots$, $Y_m=f_m$.

Let $\overline{X}_1, \overline{X}_2 \ldots \overline{X}_n$ be the true (or approximate assumed) values, and from these let $\overline{Y}_1, \overline{Y}_2 \ldots \overline{Y}_m$, and $\overline{Z}$ be derived. Then if $x_1, x_2 \ldots x_n$ are the small quantities $X_1-\overline{X}_1$, $X_2-\overline{X}_2 \ldots X_n-\overline{X}_n$,

$$\overline{Z}=Z-\frac{dZ}{dX_1}\cdot x_1-\frac{dZ}{dX_2}\cdot x_2-\ \ldots\ -\frac{dZ}{dX_n}\cdot x_n$$

* Cf. *Chauvenet's Astronomy* (5th ed.), vol. ii. p. 502.

or

$$Z=\overline{Z}+\left(\frac{\partial Z}{\partial Y_1}\cdot\frac{\partial Y_1}{\partial X_1}+\frac{\partial Z}{\partial Y_2}\cdot\frac{\partial Y_2}{\partial X_1}+\ \ldots\ +\frac{\partial Z}{\partial Y_m}\cdot\frac{\partial Y_m}{\partial X_1}\right)x_1+\ \ldots$$

Hence

$$[\epsilon(Z)]^2=\left[\frac{\partial Z}{\partial Y_1}\cdot\frac{\partial Y_1}{\partial X_1}+\frac{\partial Z}{\partial Y_2}\cdot\frac{\partial Y_2}{\partial X_1}+\ \ldots\ +\frac{\partial Z}{\partial Y_m}\cdot\frac{\partial Y_m}{\partial X_1}\right]^2[\epsilon(X_1)]^2$$

$$+\ \ldots$$

$$+\left[\frac{\partial Z}{\partial Y_1}\cdot\frac{\partial Y_1}{\partial X_n}+\frac{\partial Z}{\partial Y_2}\cdot\frac{\partial Y_2}{\partial X_n}+\ \ldots\ +\frac{\partial Z}{\partial Y_m}\cdot\frac{\partial Y_m}{\partial X_n}\right]^2[\epsilon(X_n)]^2$$

$$=\sum_{i=1}^{i=n}[\epsilon(X_i)]^2\left[\sum_{j=1}^{j=m}\frac{\partial Z}{\partial Y_j}\cdot\frac{\partial Y_j}{\partial X_i}\right]^2$$

7. On the other hand

$$Y_j=\overline{Y}_j+\frac{\partial Y_j}{\partial X_1}\cdot x_1+\frac{\partial Y_j}{\partial X_2}\cdot x_2+\ \ldots\ +\frac{\partial Y_j}{\partial X_n}\cdot x_n$$

and $[\epsilon(Y_j)]^2=\left(\frac{\partial Y_j}{\partial X_1}\right)^2[\epsilon(X_1)]^2+\left(\frac{\partial Y_j}{\partial X_2}\right)^2[\epsilon(X_2)]^2$

$$+\ \ldots\ +\left(\frac{\partial Y_j}{\partial X_n}\right)^2[\epsilon(X_n)]^2$$

But $Z=\overline{Z}+\frac{\partial Z}{\partial Y_1}\cdot y_1+\frac{\partial Z}{\partial Y_2}\cdot y_2+\ \ldots\ +\frac{\partial Z}{\partial Y_m}\cdot y_m$

where $y_1, y_2 \ldots y_m$ are the small quantities $Y_1-\overline{Y}_1$, $Y_2-\overline{Y}_2 \ldots Y_m-\overline{Y}_m$. Hence if we ignored the involved character of $Y_1, Y_2 \ldots Y_m$ in relation to the observed quantities, we should derive

$$[\epsilon(Z)]^2=\left(\frac{\partial Z}{\partial Y_1}\right)^2[\epsilon(Y_1)]^2+\left(\frac{\partial Z}{\partial Y_2}\right)^2[\epsilon(Y_2)]^2+\ \ldots$$

$$+\left(\frac{\partial Z}{\partial Y_m}\right)^2[\epsilon(Y_m)]^2$$

$$=\left[\left(\frac{\partial Z}{\partial Y_1}\right)^2\left(\frac{\partial Y_1}{\partial X_1}\right)^2+\left(\frac{\partial Z}{\partial Y_2}\right)^2\left(\frac{\partial Y_2}{\partial X_1}\right)^2+\ \ldots\right.$$

$$\left.+\left(\frac{\partial Z}{\partial Y_m}\right)^2\left(\frac{\partial Y_m}{\partial X_1}\right)\right][\epsilon(X_1)]^2$$

$$+\ \ldots$$

$$+\left[\left(\frac{\partial Z}{\partial Y_1}\right)^2\left(\frac{\partial Y_1}{\partial X_n}\right)^2+\left(\frac{\partial Z}{\partial Y_2}\right)^2\left(\frac{\partial Y_2}{\partial X_n}\right)^2+\ \ldots\right.$$

$$\left.+\left(\frac{\partial Z}{\partial Y_m}\right)^2\left(\frac{\partial Y_m}{\partial X_n}\right)^2\right][\epsilon(X_n)]^2$$

$$=\sum_{i=1}^{i=n}[\epsilon(X_i)]^2\sum_{j=1}^{j=m}\left[\frac{\partial Z}{\partial Y_j}\cdot\frac{\partial Y_j}{\partial X_i}\right]^2$$

This result differs in general from that previously obtained, and shows that the process on which it is based is fallacious. Thus the transformation from observed to related quantities gives a result the precision of which must be obtained by a single direct operation, and not by corresponding consecutive operations.

8. There are, however, particular transformations to which the foregoing statement does not apply. The conditions which must be satisfied by these will be obtained by comparing the results expressed in §§ 6 and 7. These become identical if the coefficients of $\frac{\partial Z}{\partial Y_j} \cdot \frac{\partial Z}{\partial Y_{j'}}$ in the former are equated to 0.

Hence we have $\frac{1}{2} m (m-1)$ conditions of the form

$$\sum_{i=1}^{i=n} [\epsilon(X_i)]^2 \frac{\partial Y_j}{\partial X_i} \cdot \frac{\partial Y_{j'}}{\partial X_i} = 0$$

in which $j \not> m$, $j' \not> m$, and $j \neq j'$.

9. Thus, for example, let $Z=\phi(\xi, \eta)$, where $\xi=f_1(x, y)$, $\eta=f_2(x, y)$, and x, y are quantities directly determined with equal precision, so that $\epsilon_x=\epsilon_y$. The above condition becomes

$$\frac{\partial \xi}{\partial x} \cdot \frac{\partial \eta}{\partial x} + \frac{\partial \xi}{\partial y} \cdot \frac{\partial \eta}{\partial y} = 0$$

Hence if the curves $\xi=c_1$ and $\eta=c_2$ in the xy plane intersect orthogonally, the precision of Z, for all forms of the function ϕ, can be derived from that of ξ and η.

Or again, the case may be considered of three quantities directly determined with equal precision. Here $Z=\phi(\xi, \eta, \zeta)$ and $\xi=f_1(x, y, z)$, $\eta=f_2(x, y, z)$, $\zeta=f_3(x, y, z)$. The conditions to be satisfied are

$$\frac{\partial \xi}{\partial x} \cdot \frac{\partial \eta}{\partial x} + \frac{\partial \xi}{\partial y} \cdot \frac{\partial \eta}{\partial y} + \frac{\partial \xi}{\partial z} \cdot \frac{\partial \eta}{\partial z} = 0$$

$$\frac{\partial \eta}{\partial x} \cdot \frac{\partial \zeta}{\partial x} + \frac{\partial \eta}{\partial y} \cdot \frac{\partial \zeta}{\partial y} + \frac{\partial \eta}{\partial z} \cdot \frac{\partial \zeta}{\partial z} = 0$$

$$\frac{\partial \zeta}{\partial x} \cdot \frac{\partial \xi}{\partial x} + \frac{\partial \zeta}{\partial y} \cdot \frac{\partial \xi}{\partial y} + \frac{\partial \zeta}{\partial z} \cdot \frac{\partial \xi}{\theta z} = 0$$

and show that if the measured quantities are represented by the coordinates of a point in space, and if the surfaces $\xi=c_1$, $\eta=c_2$, and $\zeta=c_3$ cut one another orthogonally, the intermediate process is legitimate. And generally it appears that quantities derived by an orthogonal transformation from equally precise observations can be treated as if they were themselves actually measured quantities.

10. The simple case of a linear binomial form will illustrate

what has been said. Suppose $Z=\lambda\xi+\mu\eta$, where $\xi=lx+my$, $\eta=l'x+m'y$. Then

$$Z=(\lambda l+\mu l')x+(\lambda m+\mu m')y$$

$$\therefore [\epsilon(Z)]^2=[(\lambda l+\mu l')^2+(\lambda m+\mu m')^2]\epsilon^2$$

But $$[\epsilon(\xi)]^2=(l^2+m^2)\epsilon^2\ ;\ [\epsilon(\eta)]^2=(l'^2+m'^2)\epsilon^2$$

Hence if ξ and η were treated as independently measured quantities we should have

$$[\epsilon(Z)]^2=[\lambda^2(l^2+m^2)+\mu^2(l'^2+m'^2)]\epsilon^2$$

which is erroneous unless $ll'+mm'=0$, *i.e.* unless the axes, considered rectangular originally, remain so on transformation.

11. The method which has been illustrated in § 4 is instructive. I consider the case of two measured quantities x and y of which the mean errors are ϵ_x and ϵ_y. Let ξ and η be two functions of x and y, so that

$$\epsilon_\xi^2=\left(\frac{\partial\xi}{\partial x}\right)^2\epsilon_x^2+\left(\frac{\partial\xi}{\partial y}\right)^2\epsilon_y^2$$

$$\epsilon^{\eta 2}=\left(\frac{\partial\eta}{\partial x}\right)^2\epsilon_x^2+\left(\frac{\partial\eta}{\partial y}\right)^2\epsilon_y^2.$$

Then combined errors of equal probability are given by

$$\begin{aligned}\text{Const.}&=\frac{(\delta x)^2}{\epsilon_x^2}+\frac{(\delta y)^2}{\epsilon_y^2}\\
&=\left(\frac{\partial x}{\partial\xi}\cdot\delta\xi+\frac{\partial x}{\partial\eta}\cdot\delta\eta\right)^2/\epsilon_x^2+\left(\frac{\partial y}{\partial\xi}\cdot\delta\xi+\frac{\partial y}{\partial\eta}\cdot\delta\eta\right)^2/\epsilon_y^2\\
&=(\delta\xi)^2\left[\left(\frac{\partial x}{\partial\xi}\right)^2/\epsilon_x^2+\left(\frac{\partial y}{\partial\xi}\right)^2/\epsilon_y^2\right]\\
&+(\delta y)^2\left[\left(\frac{\partial x}{\partial\eta}\right)^2/\epsilon_x^2+\left(\frac{\partial y}{\partial\eta}\right)^2/\epsilon_y^2\right]\\
&+2\delta\xi\ .\ \delta\eta\left[\frac{\partial x}{\partial\xi}\cdot\frac{\partial x}{\partial\eta}/\epsilon_x^2+\frac{\partial y}{\partial\xi}\cdot\frac{\partial y}{\partial\eta}/\epsilon_y^2\right]\end{aligned}$$

Now it is easily proved that

$$\frac{\partial x}{\partial\xi}=J\frac{\partial\eta}{\partial y},\ \frac{\partial y}{\partial\xi}=-J\frac{\partial\eta}{\partial x},\ \frac{\partial x}{\partial\eta}=-J\frac{\partial\xi}{\partial y},\ \frac{\partial y}{\partial\eta}=J\frac{\partial\xi}{\partial x}$$

where $$J=\frac{\partial(x,y)}{\partial(\xi,\eta)}=\frac{\partial x}{\partial\xi}\frac{\partial y}{\partial\eta}-\frac{\partial y}{\partial\xi}\frac{\partial x}{\partial\eta}$$

Hence the previous expression becomes

$$\text{Const.} = J^2(\delta\xi)^2\left[\left(\frac{\partial\eta}{\partial y}\right)^2/\epsilon_x^2 + \left(\frac{\partial\eta}{\partial x}\right)^2/\epsilon_y^2\right]$$

$$+ J^2(\delta y)^2\left[\left(\frac{\partial\xi}{\partial y}\right)^2/\epsilon_x^2 + \left(\frac{\partial\xi}{\partial x}\right)^2/\epsilon_y^2\right]$$

$$-2J^2\delta\xi \,.\, \delta y\left[\frac{\partial\eta}{\partial y}\cdot\frac{\partial\xi}{\partial y}/\epsilon_x^2 + \frac{\partial\eta}{\partial x}\cdot\frac{\partial\xi}{\partial x}/\epsilon_y^2\right]$$

$$= J^2(\delta\xi)^2\epsilon_\eta^2/\epsilon_x^2\epsilon_y^2 + J^2(\delta y)^2\epsilon_\xi^2/\epsilon_x^2\epsilon_y^2$$

$$-2J^2\delta\xi \,.\, \delta\eta\left[\frac{\partial\xi}{\partial x}\cdot\frac{\partial\eta}{\partial x}\epsilon_x^2 + \frac{\partial\xi}{\partial y}\cdot\frac{\partial\eta}{\partial y}\epsilon_y^2\right]/\epsilon_x^2\epsilon_y^2$$

$$\therefore\ (\delta\xi)^2/\epsilon_\xi^2 + (\delta\eta)^2/\epsilon_\eta^2 = \text{const.}$$

on division by $J^2\epsilon_\xi^2\epsilon_\eta^2/\epsilon_x^2\epsilon_y^2$ (considered constant), if the condition

$$\frac{\partial\xi}{\partial x}\cdot\frac{\partial\eta}{\partial x}\epsilon_x^2 + \frac{\partial\xi}{\partial y}\cdot\frac{\partial\eta}{\partial y}\epsilon_y^2 = 0$$

is satisfied. This for the case $m=n=2$ agrees perfectly with the general conditions for independence previously found. The method employed here has the advantage that it indicates the nature of the function which the condition fulfils.

Oxford: 1901 *March* 2.

Observations of Leonids, 1900 *November* 15–16, *made at the Royal Alfred Observatory, Mauritius.*

(*Communicated by T. Folkes Claxton.*)

No.	Observer.	1900. Mauritius Civil Time. d	h m s	Apparent size (in Star Magnitudes).	Duration in secs.	Colour.	Train.	From R.A. °	From Dec. °	To R.A. °	To Dec. °
1	O.	15	0 25 11	>1	2	Blue	5 secs.	101	−15	112	0
2	O.		0 56 21	2	1⅓	Bluish	Slight, 5 secs.	112	+30	131	+20
3	P.		2 27 56	2	1	Bluish	None	112	+30	124	+40
4	Or.		2 56 39	>1	2⅕	Bluish	Long, 2 secs.	146	0	105	+48
5	W.		3 23 36	2	1½	White	Slight, ½ sec.	146	+10	135	+3
6	W.		4 3 51	2	1	Bluish	None	160	−11	163	−20
7	W.		4 14 55	1	⅓	Bluish white	None	177	−50	190	−58
8	W.	16	0 56 44	1	1	Red	None	128	−28	139	−24
9	W.		0 15 0	1	1	Bluish white	1½ sec.	110	+8	109	+20
10	O.		2 30 11	1½	½	Bluish	Slight	131	+22	145	+15
11	O.		2 43 10	2	2	Bluish white	1 sec.	161	−27	139	−40

Watch was kept by four observers from November $13^d\ 23\frac{1}{2}^h$ to $14^d\ 2^h$, and by one observer until $14^d\ 4^h$. No *Leonids* were seen, although the weather was favourable.

From $14^d\ 20^h$ to $22^h\ 30^m$ watch was kept by one observer at intervals: from $15^d\ 0^h$ to 3^h continuously by three observers, and by four observers until $4\frac{1}{2}^h$ (daylight). Clouds at frequent intervals throughout.

$15^d\ 0^h\ 48^m$. Moon rose from behind cloud.

$15^d\ 1^h\ 35^m$. Large amount of cloud in neighbourhood of radiant, rain falling heavily to northward. None fell at observatory.

$15^d\ 1^h\ 45^m$. Rain extending from north to west. Lunar rainbow developed during this shower.

Watch kept by two observers on 16th, and at intervals by one observer on November 17.

Initials: W., O., Or., P.=Messrs. Walter, N. V. Olivier, L. N. Olivier, and Piveteau.

Observations of the Partial Eclipse of the Sun 1900 *November* 22 *made in Western Australia.*

(*Communicated by W. Ernest Cooke, Government Astronomer.*)

The partial eclipse of the Sun was observed at the Perth Observatory, W.A., on 1900 November 22. Instrument 10-inch refractor.

		h	m	s
G.M.T. of first contact	November 21	19	37	26·82
„ last „	„	22	06	38·28

The Moon's edge passed the first of two small spots at $19^h\ 52^m\ 50^s{\cdot}28$.

Observations of a solar blackened bulb and a dry bulb thermometer in a Stevenson's screen were taken at the observatory at Carnarvon, near Shark's Bay, and at a small island in Shark's Bay, as nearly as possible in the central path. These observations are enclosed herewith.

Photographs were also taken at various times during the eclipse. The negatives are preserved, but no special measurements have been made on them.

Greenwich Mean Time.	Perth Observatory. Solar Max. in Vacuo.	Dry Bulb.	Difference.	Faure Island, Shark's Bay. Solar Max. in Vacuo.	Dry Bulb.	Difference.	Carnarvon. Solar Max. in Vacuo.	Dry Bulb.	Difference.
h m	°	°	°	°	°	°	°	°	°
18 00	...	...	...	141·3	83·0	58·3	...	...	...
15	...	...	...	141·0	82·4	58·6	...	...	...
30	...	...	...	140·2	81·8	58·4	...	...	...
45	...	...	...	138·7	81·9	56·8	...	...	...
19 00	...	69·2	...	137·4	81·1	56·3	138·4	81·3	57·1
10	...	...	...	136·4	80·3	56·1	...	...	...
15	...	...	...	...	...	...	135·1	81·7	53·4
20	...	...	...	135·3	79·8	55·5	...	...	...
30	121·8	70·0	51·8	126·0	78·6	47·4	129·4	81·9	47·5
35	122·6	69·6	53·0	124·9	79·0	45·9	...	...	...
40	121·2	70·7	50·5	129·8	79·0	50·8	...	...	...
45	120·5	69·0	51·5	125·2	78·3	46·9	120·8	80·0	40·8
50	121·0	69·6	51·4	124·0	78·1	45·9	...	...	...
55	118·1	69·0	49·1	124·1	77·8	46·3	...	...	...
20 00	116·0	69·0	47·0	120·3	77·2	43·1	113·7	78·8	34·9
05	112·0	68·2	43·8	118·8	76·7	42·1	...	...	...
10	107·9	68·6	39·3	116·8	76·8	40·0	...	...	...
15	104·5	68·6	35·9	116·3	75·9	40·4	99·9	78·0	21·9
20	102·3	68·4	33·9	112·4	75·8	36·6	...	...	...
25	99·1	68·0	31·1	110·0	75·4	34·6	...	...	...
30	96·1	67·6	28·5	...	...	...	93·5	76·8	16·7
32	...	...	...	104·0	74·8	29·2	...	...	...
35	92·0	67·0	25·0	102·3	74·3	28·0	...	...	...
40	88·2	66·5	21·7	99·2	73·9	25·3	...	...	...
45	84·5	66·4	18·1	95·0	74·0	21·0	84·0	75·7	8·3
50	81·0	66·3	14·7	91·0	73·4	17·6	...	...	...
55	78·4	66·0	12·4	87·0	73·1	13·9	...	...	...
21 00	76·8	66·2	10·6	82·6	72·6	10·0	77·9	74·7	3·2
03	...	...	...	80·3	72·4	7·9	...	...	...
05	76·3	66·0	10·3	79·0	72·4	6·6	...	...	...
07	...	...	...	78·0	72·3	5·7	...	...	...
10	77·0	66·0	11·0	77·0	72·1	4·9	...	...	...
12	...	...	...	77·0	72·0	5·0	...	...	...
15	78·6	66·2	12·4	77·5	72·3	5·2	74·6	74·0	0·6
18	...	...	...	78·6	72·0	6·6	...	...	...
20	80·3	66·1	14·2	79·5	72·0	7·5	...	...	...
22	...	...	...	80·6	72·0	8·6	...	...	...

Greenwich Mean Time.	Perth Observatory. Solar Max. in Vacuo.	Dry Bulb.	Difference.	Faure Island, Shark's Bay. Solar Max. in Vacuo.	Dry Bulb.	Difference.	Carnarvon. Solar Max. in Vacuo.	Dry Bulb.	Difference.
h m	°	°	°	°	°	°	°	°	°
21 25	83·0	66·0	17·0	82·3	72·1	10·2	...	...	...
27	...	...	...	84·0	72·0	12·0	...	...	...
30	85·7	66·0	19·7	85·7	71·8	13·9	77·0	74·0	3·0
33	...	...	...	87·2	72·0	15·2	...	...	...
35	88·1	66·0	22·1	88·7	71·9	16·8	...	...	...
38	...	...	...	90·2	72·0	18·0	...	...	...
40	90·7	66·4	24·3	91·5	72·0	19·5	...	...	...
42	...	...	...	92·3	72·0	20·3	...	...	...
45	91·8	66·4	25·4	93·9	72·1	21·8	80·0	74·0	6·0
47	...	...	...	94·7	72·2	22·5	...	...	...
50	93·0	66·3	26·7	96·0	72·2	23·8	...	...	...
52	...	...	...	96·4	72·0	24·4	...	...	...
55	93·2	66·2	27·0	97·2	71·8	25·4	...	...	...
57	...	...	...	98·0	72·0	26·0	...	...	...
22 00	93·4	66·1	27·3	98·3	71·7	26·6	91·8	74·0	17·8
02	...	...	...	98·6	71·6	27·0	...	...	...
05	93·1	66·1	27·0	98·6	71·6	27·0	...	...	...
07	...	...	...	98·8	71·4	27·4	...	...	...
10	92·1	66·0	26·1	98·2	71·2	27·0	...	...	...
12	...	...	...	98·0	71·2	26·8	...	...	...
15	...	...	...	97·4	71·1	26·3	82·3	73·8	8·5
20	...	...	...	95·6	71·0	24·6	...	...	...
25	...	...	...	93·1	70·7	22·4	...	...	...
30	...	...	...	90·2	70·3	19·9	...	...	...
35	...	...	...	86·7	70·3	16·4	73·5	72·7	0·8
38	...	...	...	83·7	70·3	13·4	...	...	...

Barometer, Faure Island, Shark's Bay. Height above M.S.L. about 25 feet.

G.M.T.	Uncorrected Baro.	Alt. Therm.	G.M.T.	Uncorrected Baro.	Alt. Therm.
h m	in.	°	h m	in.	°
18 00	29·990	86·6	20 30	29·907	75·5
30	·980	85·7	21 00	·900	73·2
19 00	·952	84·0	30	·898	72·0
30	·936	82·0	22 00	·906	72·0
20 00	·925	79·8	30	·920	70·0

Wind fresh to strong, S.S.W. to W.S.W.

Position of Observing Stations.

	Latitude.	Longitude.
Perth Observatory	31° 57′ S.	115° 51′ E.
Faure Island, Shark's Bay	25 53	113 52
Carnarvon	24 54	113 39

Perth Observatory, W.A.:
1900 *December* 15.

Occultations of Jupiter and his Satellites, 1900 *September* 29, *observed at Windsor, New South Wales.* By John Tebbutt.

This phenomenon was observed by me under very good conditions with the 8-inch equatorial refractor and a power of 74 diameters. The times of disappearance at the Moon's dark limb, which was well seen, were very satisfactorily observed. That part of the dark limb projected on the planet's disc was serrated in consequence of the lunar peaks, and appeared almost black by contrast. The disappearances of the satellites were, of course, not instantaneous, the times recorded being those at which the last rays vanished. Of the satellites, III. occupied about two seconds, I. about 1½ second, II. about 1¼ second, and IV. about 1½ second, in disappearing. Notwithstanding that the Moon's bright limb was steady and well defined, it was impossible to observe the actual reappearances of the satellites, the times being probably from one to two seconds late. Satellite IV. was very faint at the reappearance, and this phase for the planet's western limb was missed. The predicted phases for the planet had been kindly provided by Mr. C. J. Merfield, of Sydney. The following are the observed local sidereal and mean times of the phenomenon :—

	Sidereal Time. h m s	Mean Time. h m s
Disappearance of Satellite III.	20 1 32·0	7 30 47·2
Contact of Planet's Western Limb	20 11 58·9	7 41 12·3
Disappearance of Planet's Eastern Limb ...	20 13 27·7	7 42 41·0
Disappearance of Satellite I.	20 15 39·1	7 44 52·0
Disappearance of Satellite II.	20 18 29·1	7 47 41·5
Disappearance of Satellite IV.	20 32 44·9	8 1 55·0
Reappearance of Satellite III.	21 9 35·7	8 38 39·7
Contact of Planet's Eastern Limb	21 18 21·6	8 47 24·3
Reappearance of Satellite I.	21 19 37·6	8 48 40·0
Reappearance of Satellite II.	21 22 5·1	8 51 7·1
Reappearance of Satellite IV.	21 31 48·1	9 0 48·5

Observatory, Peninsula, Windsor, N.S. Wales:
1900 *November* 23.

THE FOLLOWING REPORTS OF OBSERVATORIES WERE RECEIVED TOO LATE FOR INSERTION IN THE ANNUAL REPORT OF THE COUNCIL :—

Melbourne Observatory.

Meridian Observations made with the 8-inch Transit Circle.

Observations in	R.A.	N.P.D.
Azimuth stars	299	134
Clock ,,	1676	...
List ,,	1160	1173
Total ...	3135	1307

The list stars were selected from the plates of the *Astrophotographic Catalogue* to be used for the reduction of these plates. The total number of this class of stars observed at Melbourne at least three times, up to December 31 last, was 3,534.

The separate results and annual catalogue for 1899 have been prepared, and the reductions of all meridian observations for 1900 are nearly completed.

The General Catalogue for 1890, which contains 3,100 stars, and includes all the observations made with the 8-inch Transit Circle since its erection in 1884 to the year 1893 inclusive, has also been completed, and is now undergoing a general revision and an independent re-computation of the precessions.

Astrophotographic Operations.—

Chart plates with triple exposures of 30^m each ...	45
Chart plates with single exposures of 60^m ...	56
Catalogue plates (Duplicate Series)	46
Test plates on South Polar region	31
Test plates on Oxford typical regions	10
Test plates for trials, centre, &c.	29
Plates for investigating magnitudes	9
Total number of plates obtained	226

Six chart plates with triple exposure, 7 chart plates with single exposure, and 2 catalogue plates have been rejected as defective.

The series of chart plates with single exposure of 60^m, covering the Melbourne zones of even degrees of declination, is practically completed, only some 12 rejected plates remaining to be obtained again. As the last Paris Conference did not come to

any definite conclusion as to the process and form to be adopted for the publication of the chart by the co-operating observatories, it is intended to initiate experiments to ascertain whether it will be possible here in Melbourne (both in regard to cost and excellence of work) to reproduce our chart plates for publication, taking for our model and standard the beautiful Paris charts.

Measurement of Plates.—See joint report.

Equatorials.—No systematic work has been done with the Great Telescope and other equatorials. These instruments have been used only occasionally for examination of comets and planets, and for visitors.

Photoheliograph.—Sixteen pictures of the Sun were obtained during the year on special occasions.

Terrestrial Magnetism.—Photographic registration of the variation of magnetic elements and absolute measurements have been carried on as in former years.

The measurement and reduction of magnetic curves of past years has been continued by four young computers.

7,911 day curves have been measured and reduced during the year 1900, including the records of 1881, 1884, 1885, 1886, 1887, 1888, 1889.

The total number of curves now measured is 12,206, which is about two-fifths of the whole amount required to bring the arrears up to the end of 1897.

Cloud Photography.—Sixty-five pairs of simultaneous pictures were taken for determination of cloud height and velocity. The reduction of cloud observations made for the International Meteorological Committee during the year 1897 and the measures of cloud photographs have been carried on by two young computers.

The reductions are well advanced.

Meteorological and Miscellaneous Work.—Amongst the general routine duties which have been carried on as in former years for public requirements are the following :—

The Time Service.—The meteorological service, which now includes 672 Victorian stations. The testing of surveying, nautical, and meteorological instruments, and rating of chronometers for the shipping, &c.

The observation and registration of tides.

Prolonged sickness prevailed amongst some of the members of the permanent staff in the course of the past year, and one of the temporary assistants died last December.

Measurement of the Sydney and Melbourne Plates of the Astrophotographic Catalogue. Joint Report for Sydney and Melbourne.

The measuring instrument made by Repsold & Söhne on the plan of Sir David Gill, which, as was announced in the joint report of last year, reached the Melbourne Observatory in January 1900, has been constantly employed in the systematic measurement of the catalogue plates since last March.

The verdict on this instrument, as far back as last April, was that "In point of construction and workmanship it fully bears out the reputation of the makers, and experience so far gained in Melbourne in working with it confirms the reality of all the advantages and capabilities ascribed to it by Dr. Gill."

All the adjustments were made with very little trouble within the degree of accuracy and in the manner described by Sir David Gill in *Monthly Notices*, vol. xlix. page 61 *et seq.*, and remained very constant.

This instrument is far easier, far less fatiguing, and far more satisfactory to work with than any other instrument previously used here for the measurement of plates. The rate of measuring has increased considerably with experience. At present about 170 stars can be measured in one hour, and, on an average, a plate containing 400 stars is measured in the direct and reverse position by two observers, each recording for the other in alternate periods of one hour, in one working day (about $6\frac{1}{2}$ hours), including the revision of measures differing by $0''\cdot6$ or more, in the reverse and direct position, which discrepancy measures amount, at most, to 3 per cent.

The rate of measuring with the Melbourne micrometers is only one-third of that obtainable with the Repsold instrument.

Owing to this fact, and to unavoidable delay in pushing forward the measuring machine which is being made at the Sydney Observatory, we ordered last May another instrument from the Repsolds similar to the first, which we hope will reach Melbourne in a few months.

Thirty-six Sydney plates and fifty-one Melbourne plates have been completely measured, containing 49,697 stars.

The average number of stars on a single plate is, approximately, 1,000 for Sydney plates, and under 300 for the Melbourne plates.

As soon as the measuring bureau, which consists of six young ladies, is fully equipped with three quick-measuring instruments it is estimated, from the present rate at which the work is proceeding, that the work of the bureau for a year consisting of about 250 full working days will be probably represented by the measures of coordinates in direct and reverse position of some 300,000 stars.

Perth Observatory, Western Australia.

Once more, and it is hoped for the last time, the work of this observatory has been almost exclusively meteorological.

Some very useful work has, however, been accomplished, and the way made ready for the commencement of astronomical observations. In particular a book on the climate of Western Australia has been prepared. This has necessitated a thorough inspection of all records which were taken prior to the establishment of the observatory, checking all the additions, &c., and entering the results in ledgers. Its preparation has taken three or four years, as most of the officers' time was required for the routine work, but it is at last ready for the printer.

The routine meteorological work of course includes the issue of forecasts, which have been again very successful, even the public appearing to have some faith in them. The following were prepared during 1900:—

1. For the whole State, issued at noon daily in connection with a weather map of the whole of Australia.

2. For the whole State, communicated to the Press daily at 8 P.M., in conjunction with a weather report from sixteen selected stations.

3. For the goldfields districts, telegraphed each evening at 8 P.M. to five daily newspapers circulated in that region.

4. For Perth and its immediate neighbourhood only, issued at 9 A.M. and exhibited in a pictorial form, similar to that of the London *Daily Graphic*.

The following were the percentage results for 1900:—

	1	2	3
Correct	90	93	87
Partially correct	9	5	11
Wrong	1	2	2

The results of No. 4 were not tabulated, but the forecasts were almost invariably correct.

In astronomy the transit circle was used mainly for time purposes. Messrs. Joscelyne and Curlewis each made a determination of latitude from morning and evening circumpolars on three winter nights. Their results were respectively

$$31^\circ\ 57'\ 09''{\cdot}42 \quad \text{and} \quad 31^\circ\ 57'\ 09''{\cdot}60,$$

which are in satisfactory accordance with one another and with the value already obtained by the Government astronomer, viz. $31^\circ\ 57'\ 09''{\cdot}63$. None of these results have been corrected for errors of division.

The astrographic equatorial has been used almost entirely for the benefit of visitors. It was inevitable that many people

should wish to inspect the new observatory, and, in order to gratify as many as possible, parties of twelve to twenty were invited about three or four evenings every week. This popular state of affairs ceased on December 31, and in future only three evenings per month will be available for this purpose. A few students received instruction from the Government astronomer in practical astronomy during the early spring evenings.

The outlook now is decidedly more promising. At the request of the International Committee the Western Australian Government has agreed to allow the astronomer to take a share in the Photographic Durchmusterung, and additional assistance has been authorised. The zone −32° to −40° has been assigned, and it is probable that both astrographic telescope and transit circle will be in full work during the latter half of 1901.

Errata.

In Mr. H. C. Plummer's paper, page 146, Equation (3), *for* sin δ sin $-\phi$ *read* sin δ sin ϕ.

In Annual Report (Progress of Meteoric Astronomy), page 246, 6th line from top, *for* perihelion *read* aphelion.

MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

VOL. LXI. APRIL 12, 1901. No. 6

DR. J. W. L. GLAISHER, F.R.S., PRESIDENT, in the Chair;

The Rev. Richard Coad Pryor, M.A., The Rectory, Grafton Regis, Stony Stratford,

was balloted for and duly elected a Fellow of the Society.

The following Candidates were proposed for election as Fellows of the Society, the names of the proposers from personal knowledge being appended :—

Francis William Crook, B.A., Barrister-at-Law, Secretary to the Technical Education Committee of the Kent County Council, 4 Overcliff, Gravesend (proposed by Sir D. L. Salomons);

Frank Lowman, B.A., Lecturer in Science, &c., St. John's College, Battersea, S.W. (proposed by A. E. Moore); and

Charles Nielsen, 15 Cliff Terrace, Hartlepool (proposed by Sir R. S. Ball).

Eighty-eight presents were announced as having been received since the last meeting, including amongst others :—

Eighty-nine charts of the Astrographic Chart of the Heavens, from photographs made at the Observatories of Algiers, Paris, and Toulouse, presented by the French Government; collection

of about 20,000 titles of astronomical works made by the late Mr. G. J. Symons, presented by his executors; The Cape Photographic Durchmusterung, part 3, and Researches on Stellar Parallax, presented by the Royal Observatory, Cape of Good Hope; Sir W. Hamilton, Elements of Quaternions, vol. ii., second edition, edited by C. J. Joly, presented by the Editor; Photograph of the Solar Eclipse of May 1900, by Professor E. E. Barnard, presented by Professor Barnard and Mr. Ritchey; photograph of the cluster in *Hercules* and of a portion of the Moon, made with the 40-inch telescope of the Yerkes Observatory, presented by Professor G. E. Hale; a siderostat by Hilger, presented by Mr. Alex. Foote.

Second Note on Photographs of the Spectrum of Nova Persei; Correspondence with the Spectrum of η Argûs. By F. McClean, LL.D., F.R.S.

The complete list of photographs of the spectrum of *Nova Persei* obtained by me between February 25 and April 9 is as follows. The magnitudes were approximately estimated from neighbouring stars:—

1901.		Mag.		1901.		Mag.	
Feb.	25	1	visual spectrum observed	March	18	4	2 photographs
	27	1¼	2 photographs		22	4½	1 „
	28	1½	2 „		24	5	2 „
March	1	2	3 „		27	4¼	2 „
	2	2	1 „		31	4½	1 „
	3	2½	3 „	April	1	4¼	nil „
	5	2½	1 „		4	4½	1 „
	6	3¼	1 „		5	4½	2 „
	9	4	3 „		7	5½	1 „
	12	4½	2 „		8	4¼	nil „
					9	4½	1 „

Making in all 31 photographs taken on 18 nights.

These photographs have been enlarged for comparison. Four of them have been selected and mounted together with an approximate scale of wave lengths (plate No. 1, shown at Meeting).

These were taken on the following dates: February 27, March 3 and 12, and April 5. The hydrogen absorption lines were clearly shown on the photographs up to March 18. On March 22 and subsequently they could not be distinguished.

Lantern slides of the same four spectra were also shown. The two earlier ones show the extent of the spectrum photographed from (Hι) to near (D).

The spectra shown by me on March 8 were accompanied by a comparison spectrum of β *Crucis* in order to show the apparent absence of the Helium lines. They were also accompanied by a comparison spectrum of *Sirius* to show the strong similarity between that spectrum and the spectrum of *Nova*. I have now also mounted the spectrum of a *Cygni* for comparison with *Nova*. It is a star of the *Sirian* type, with some exceptionally strong lines. It had already been compared by me with *Nova*, and I revert to it on account of the further resemblance it bears to the bright line spectrum of η *Argûs*.

The spectrum of η *Argûs* was sent me by Sir David Gill from the Cape Observatory in January 1899. He then wrote: "I am sending you by this mail a prism picture of the neighbourhood of η *Argûs*, exposure one hour. The wonderful spectrum near the centre of the field is that of η *Argûs*. There are lots of other bright-line spectra on the plate, as Pickering has already mentioned, but he has apparently no notion what a spectrum η *Argûs* has." This plate was shown in the lantern.

The spectrum of η *Argûs* was enlarged about ten and a half times to the same scale as other enlargements of stellar spectra, so as to be able to compare it with them. On recently comparing it with the spectrum of *Nova Persei*, I found a close correspondence between the bright-line spectrum of η *Argûs* and the absorption spectrum of *Nova Persei*. This correspondence is especially marked from Hγ to Hβ, and the correspondence holds good with the absorption spectrum of a *Cygni*. These three spectra have been mounted together for comparison (plate No. 2 shown at the meeting), and a scale of wave lengths is attached to them.

The absorption spectrum of *Nova Aurigæ* has been plotted to the same scale from the photographs published by Campbell (*Astronomy and Astrophysics*, 1892) and by Frost (*Astronomical Spectroscopy*, 1894). It corresponds closely with the absorption spectrum of *Nova Persei*, and goes to establish the fact that that absorption spectrum is genuine, and not the mere effect of contrast in the spaces between the bright bands. Except the hydrogen bands, the bright line spectrum of *Nova Persei* is difficult to distinguish. To some extent it appears to duplicate the absorption bands, as with *Nova Aurigæ*, and to form a background on which the absorption spectrum is visible.

The spectra of *Nova Normæ* and *Nova Aurigæ* have been compared by Pickering (*Annals of Harvard Observatory*, vol. 26) and found to be "almost identical." It thus appears that the absorption spectra of the three *Novæ*—viz. *Nova Persei*, *Nova Normæ*, and *Nova Aurigæ*—correspond closely with the bright line spectrum of η *Argûs*. It seems possible that the *Novæ* may owe their passing brilliancy to circumstances similar to those

which give rise to the variable brilliancy of *η Argûs*, although, of course, this is only conjectural.

The correspondence with *α Cygni* furnishes an indication of the origin of these spectra. The spectrum of *α Cygni* differs from that of *Sirius* mainly in the strength of its lines. I have previously (*Comparative Spectra of Stars*, *Phil. Trans.*, vol. 191) attributed the characteristic lines of the Sirian stars to "calcium and titanium rather than to iron, although that spectrum is also present in an incipient form."

April 12, 1901.

Addendum.

Additional photographs of spectrum of *Nova Persei* :—

1901.	Mag.	Photographs	1901.	Mag.	Photograph
April 17	$5\frac{1}{4}$	nil	April 21	6	1
18	$4\frac{1}{4}$	2	22	6	nil
20	6	1	27	$4\frac{3}{4}$	1

April 28, 1901.

The Spectrum of Nova Persei. Note 2.
By Rev. W. Sidgreaves.

The bright hydrogen bands have preserved their general character of strength and breadth throughout the month of March and up to April 4, the date of the last photograph. At the beginning and end of March they were well marked by fine central reversals; in the middle of March they were crossed by two, and in some cases three, lines of greater brightness; and on April 4 Hζ showed a line of very pronounced maximum strength to the violet side of its wave-length centre.

The dark hydrogen lines showed their comparatively narrow width on March 7, when the bright bands had paled enough to unmask the red side margins of their dark companions. On March 12 the dark lines were well defined doubles, with the violet side components weaker. On the 21st and 22nd the weaker components were lost, and the series became one of very fine single lines. After the 22nd no sign of the dark series has appeared on the plates.

The relative displacement of the two series is very great; and, apart from direct comparison with the hydrogen tube, it is possible to say, with great probability, that the source of the hydrogen bright bands is comparatively stationary, and that the source of the dark lines, if their displacements are to be

attributed to motion, must be at a velocity far too great for any assignable physical cause. The measured lengths from $H\beta$ to $H\gamma$, to $H\delta$, to $H\epsilon$, to $H\zeta$, and to $H\eta$ centre to centres of the bright bands, guided by the reversals, are the same as the lengths measured on the spectra of comparison stars; and the measured lengths of the same intervals in the dark line series proceed with an increasing difference, showing a longer spectrum. These differences will be given in wave-length measure in a future full report of the observations of the new star; and they will probably be found to need velocity of the order 10^3 miles to account for them by motion in the line of sight.

Stonyhurst College Observatory:
1901 *April* 7.

The Spectrum of Nova Persei. Note 3. By Rev. W. Sidgreaves.

Nova Persei as a Variable Star with a Variable Spectrum.

On March 22 it was first seen that there was a marked change in the spectrum when the star was very small, about equal to *l Persei.* A prominent bright yellow band appeared to rival $H\alpha$; and on the photograph one of the bright blue bands stood out boldly on the weak continuous spectrum as strong as $H\beta$, accompanied by three other weaker bands; and, thirdly, the bright $H\zeta$ band was extended on the violet side to double its usual width.

On March 25 and 28 the bright yellow band was the same, and the photographed spectrum was the same as on the 22nd; while the photographed spectrum of the 27th was of the same type as on the 21st and previous days: the blue bands were more masked by the stronger continuous spectrum, and $H\zeta$ was at its usual breadth. A reference to the journal of observations showed that the three dates, 22nd, 25th, 28th, were probably well marked minima of the star's light curve; and although there was only the one photograph of the spectrum on an intervening day, when the star was brighter, the yellow band had been observed through breaks in the clouds on the 24th and 26th, and was noted as not so prominent as on the three nights of minimum brightness. Since then no photograph has been obtained on a date of minimum magnitude, supposing the period to be three days; but a good photograph on April 4, when the star appeared very nearly equal to *κ Persei*, showed the same spectrum as on the 27th, and the yellow band was noted as weak.

There can be no doubt about the variations of the star's magnitude and of its continuous spectrum; these go together;

and the prominence of the yellow and blue bands at the minimum epoch is in the main the result of the greater contrast on a darker ground. But this does not appear to be enough to account for the strength of the brightest of the blue bands, and fails completely to explain the great extension of the bright H_γ band.

Whatever, therefore, be the cause of dimming the white light of the star at its minimum brightness, it does not in proportion stop its gaseous radiation.

Stonyhurst College Observatory: 1901 April 7.

Observations of the New Star in Perseus made at the Radcliffe Observatory, Oxford.

(*Communicated by Arthur A. Rambaut, M.A., Sc.D., F.R.S., Radcliffe Observer.*)

This paper is a continuation of one published in the last number of the *Monthly Notices* (pp. 348–354). It contains the results of the observations of the brightness of *Nova Persei* made at the Radcliffe Observatory since the date of the last meeting of the Society.

The estimates of brightness have been made as described in the previous paper, but the comparison stars used in these observations are situated in the immediate neighbourhood of the Nova, being all contained within the constellation Perseus. In making the comparisons, as the brightness of the star diminished, recourse was had from time to time to telescopic aid with apertures of from $1\frac{1}{4}$ in. to 10 in., as indicated in the notes.

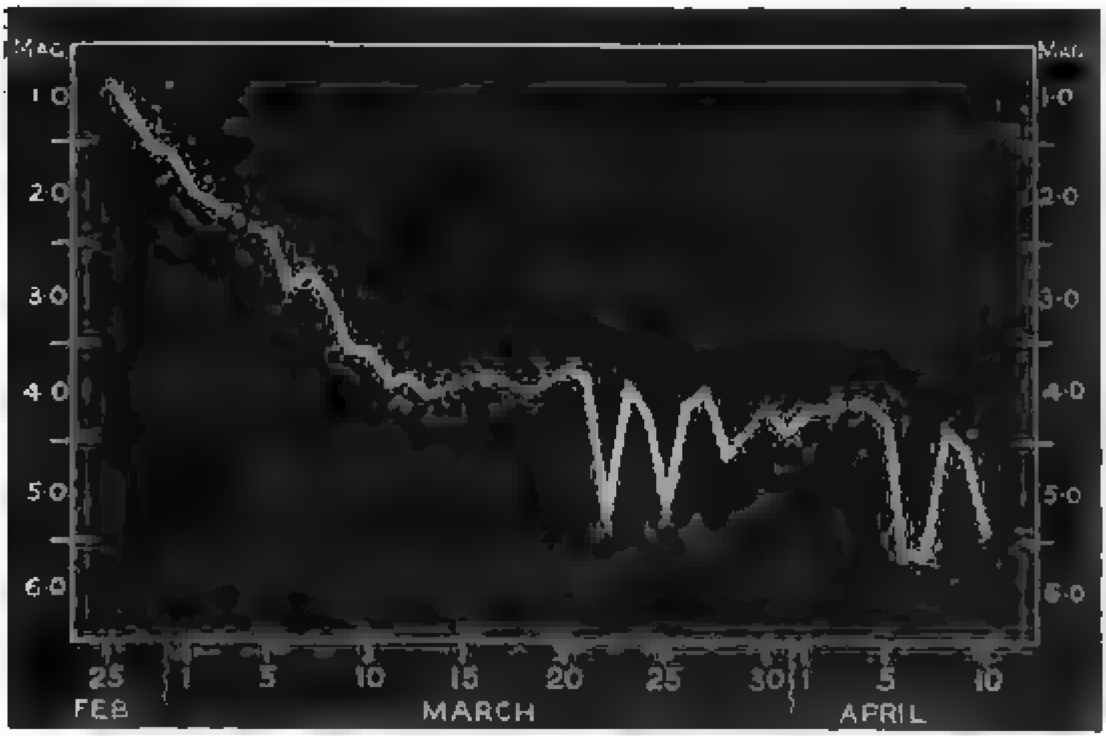
In Table I. below are given a number for reference, the names of the stars used, and the Harvard magnitudes on which our estimates are based.

Table II. contains the means of each observer's separate comparisons and the general mean for each night.

The results of our observations made since the discovery of the star are graphically represented in the accompanying figure. This diagram exhibits very clearly the variation in the brightness of the star noticed by von Glasenapp and Dunér, and corroborates the period of three days found by them. Thus we have four successive minima taking place on March 22, 25, 28, and 31, and after a cloudy interval we have two more on April 6 or 7 and 10.

A comparison of the notes on the colour of the star with the variation in its brightness seems to indicate some relation between these two phenomena, and suggests that a diminution of light is accompanied by an increase in the redness of the

star. Thus on March 21, when the star was near one of its maxima, the light is described as having "a stronger yellow tinge than when last seen." On March 25, one of the minima, the Nova is noted as "very red to-night." At the next maximum,



Magnitudes of *Nova Persei.*

March 26, the colour is described as "red with yellowish tinge." It must be admitted, however, that the observations of March 27 and 28 hardly support this view, but, on the other hand, those of March 30, April 8, and April 10 point in the same direction.

Table I.

List of Stars used for Comparison with Nova Persei.

Ref. No.	Name of Star.	Harvard Photom. Mag.	Ref. No.	Name of Star.	Harvard Photom. Mag.
29	ε Persei	3·04	45	ι Persei	4·14
30	γ Persei	3·11	46	θ Persei	4·24
31	δ Persei	3·18	47	ψ Persei	4·24
37	η Persei	3·93	48	σ Persei	4·39
38	ζ Persei	3·10	49	λ Persei	4·54
39	ρ Persei (Var.)	3·68	50	*l* Persei	4·84
40	κ Persei	3·95	51	31 Persei	4·99
41	τ Persei	3·97	52	30 Persei	5·37
42	ν Persei	4·00	53	36 Persei	5·40
43	ο Persei	4·01	54	Arg. Z + 44°, 734	6·04
44	ξ Persei	4·06	55	Arg. Z + 44°, 648	6·47

[(Revision of D.M.)

TABLE II.

Means of Estimations of Magnitude of Nova Persei.

1901	G.M.T. h m	Observer.	Reference Stars.	Mean Mags.	Adopted Magnitude for the Night.
Mar. 8	8 30	R.	29, 31	3·10	3·10
9	8 53	R.	42, 29, 40, 42, 29, 31	3·62	3·61
	9 5	W.	31, 30, 42, 37	3·57	
	9 25	A.A.R.	30, 29, 38, 42, 39, 40, 43, 44, 45, 46	3·65	
	10 30	C.	31, 29, 42, 40, 30	3·56	
10	8 7	W.	30	3·10	3·60
	9 0	R.	40, 42	3·70	
	10 0	C.	31, 29, 40, 42	3·68	
11	10 45	R.	42, 40	3·93	3·93
12	10 45	R.	31, 29, 42	3·87	3·87
13	7 45	R.	45, 42, 40	4·03	4·03
16	8 28	R.	45, 42, 40, 46, 31	3·98	3·83
	9 0	W.	37, 30, 42, 40	3·63	
18	11 0	R.	40, 42	4·00	4·00
20	9 0	R.	42, 40, 31, 30, 46	3·74	3·74
21	7 45	C.	42, 40, 31, 30	3·65	3·91
	7 50	W.	42, 40, 37, 41	4·03	
	8 20	W.	41,* 37,* 40,* 42*	4·03	
	8 35	R.	42, 40	3·70	
	10 45	C.	31, 29, 30, 42, 40	3·94	
	11 0	R.	42, 40, 45, 46	4·00	
22	7 50	R.	50	5·20	5·20
23	8 0	R.	42, 40, 42, 31, 31	3·72	3·92
	8 15	C.	42, 40	4·20	
24	8 30	R.	42, 40	4·20	4·20

* Stars used for telescopic comparisons.

1901	G.M.T.	Observer.	Reference Stars.	Mean Mags.	Adopted Magnitude for the Night.
	h m				
Mar. 25	7 55	R.	50, 52	5·15	5·15
	9 0	C.	—	5	
26	8 35	R.	40, 42, 50	4·20	4·12
	9 45	C.	40, 42	4·20	
	11 20	W.	42, 37, 42*	4·03	
27	7 40	R.	42, 40	3·95	3·98
	8 30	W.	37, 41, 40, 42	3·98	
	8 40	W.	42,* 40,* 37*	3·80	
	10 30	R.	42, 40	4·15	
	12 0	R.	40, 42	4·15	
28	8 15	W.	47, 48	4·30	4·61
	8 15	R.	50, 42, 40	4·73	
	8 30	C.	40, 50	4·60	
	8 50	W.	47, 48	4·55	
	9 0	R.	50, 42, 40	4·83	
	9 10	W.	42,* 40,* 47,* 48,* 51*	4·48	
30	6 30	R.	42,* 40*	4·15	4·14
	8 30	W.	42, 40, 48, 47	4·18	
	9 0	C.	42, 40	4·20	
	9 0	R.	42, 40	4·15	
	9 47	R.	42, 40, 45, 46	4·00	
	10 36	R.	42, 40	4·20	
	11 30	R.	42, 40	4·20	
31	8 30	R.	42, 40, 50	4·40	4·40
Apr. 1	7 30	R.	42,* 40*	4·00	4·19
	8 0	R.	42, 40, 45, 46	4·18	
	12 9	R.	42, 40	4·30	
	12 24	R.	42, 40	4·20	
4	8 15	R.	42, 40, 45, 46	4·08	4·08

1901		G.M.T. h m	Observer.	Reference Stars.	Mean Mags.	Adopted Magnitude for the Night.
Apr.	5	8 35	R.	42,* 40,* 50,* 52*	4·28	4·28
	6	9 45	C.	54,* 50*	5·60	5·60
	7	8 40	R.	52, 54, 50	5·60	5·60
	8	9 30	R.	42, 40, 50	4·43	4·40
		9 45	W.	42, 40, 47, 48, 40,* 50*	4·36	
		10 15	C.	42, 40, 50	4·50	
	9	8 30	R.	42, 40, 50	4·50	4·57
		10 15	W.	48, 50	4·60	
		10 15	C.	42, 40, 50	4·63	
	10	8 15	W.	47,* 48,* 42*, 40*, 50*, 52*	5·17	5·33
		9 10	R.	53, 54, 30	5·47	
		9 45	C.	50*	5·34	

Observers' Notes on the Estimations of Magnitudes.

March 10. Clouds passing, hazy (W.) Cloud and mist; observation rough (R). Misty. ½ wt. to 40 and 42 (C.)

March 11. Very misty. ½ wt. to 40.

March 12. Cloud and mist at times.

March 18. Rather doubtful. Clouds passing.

March 21. Nova fluctuates in brightness (C.) At $11^h\ 0^m$ Nova sensibly fainter than at 8.35 (R.)

March 22. Observed in breaks of cloud.

March 23. Observed in transient break (C.)

March 24. Observed in breaks of cloud and haze.

March 26. Nova at times momentarily equal to 40 and 42 (C.)

March 27. Nova at $12^h\ 0^m$ fainter, I think, than at $7^h\ 40^m$ (R.)

March 28. 42 brighter than 40 to-night (C.) Bright moonlight. Images sharp in the 1½-inch (W.)

March 30. Daylight observation at $6^h\ 30^m$ (R.) Cloudy; ¼ wt. to [illegible]. ½ wt. to 47 (W.)

April 5. Sky hazy.

April 6. Hurried observation in brief but clear interval.

April 7. Very clear for a short interval.

April 8. ½ wt. to 50* (W.)

April 9. Nova estimated as 0·2 fainter than last night at the same G.M.T. (W.)

General Note.—In the above comparisons it was noted that 42 (ν Persei) and 40 (κ Persei) gave slightly discrepant magnitudes for Nova Persei. Comparing the magnitudes of these two stars with a number of those given in Table I., their magnitudes were determined to be 3·90 and 4·01 respectively. The magnitudes given in the Harvard Photometry for these stars are 4·00 and 3·95. The Radcliffe estimations agree more closely with the magnitudes given in the Revision of the Harvard Photometry, viz. 3·90 and 4·07.

Observers' Remarks on Colour of Nova and Comparison Stars.

March 8. Very red to the naked eye (R.)

March 16. In Ramsden 2¼-inch 42 is bluish-white, in strong contrast to Nova, very red. I should consider a comparison between these stars to be much affected by the diversity of colour. In Barclay "Finder" Nova is very red. In the 10-inch, using power 90, very red; and with 4-inch diaphragm over the object-glass also very red (W.) Nova in Barclay is very red (C.)

March 21. Marlborough 3·2-inch. Definition exceptionally good. 42 is bluish-white, difficult to compare with Nova. With Barclay, power 80, the Nova is red, but its colour seems to have a stronger yellow tinge than when last seen by me in this telescope (W.)

March 25. Nova very red to-night in Barclay (R.)

March 26. Nova red with yellowish tinge in 1¾-inch telescope (W.)

March 27. In Marlborough telescope Nova red and disc sharp with diffraction rings. 37 is also a red star, but not nearly so darkly tinted as the Nova. This redness may account for slight differences between naked-eye and telescopic views of the stars. In Barclay, with power 90, Nova very red; its red tint has increased since I last saw the star with this instrument. Sky misty and moonlight rather strong (W.) Very red in Barclay (R.)

March 28. Nova yellowish red in 1¾-inch telescope, power 20 (W.)

March 30. Barclay equatorial, power 45. I was much struck with the absence of colour in Nova (R.) The Nova is not nearly so red in the Barclay instrument as it was on March 16 (C.)

April 8. With 1¾-inch telescope and power 20. Nova is still red, with yellowish light in centre of image; 40 is bluish-white and 14 is white (W.)

April 10. Nova, in 1¾-inch telescope and using power 20, is red and 40 is yellow. In "Finder" of Barclay, Nova is very red and has a central yellow disc. With the 10-inch and power 90 this central yellow disc and the deep ruby-red flames around it are proportionately magnified (W.)

The observers were—	Dr. Rambaut,	indicated	by	A.A.R.
	Mr. Wickham	"	"	W.
	Mr. Robinson	"	"	R.
	Mr. McClellan	"	"	C.

Radcliffe Observatory, Oxford:
1901 *April* 11.

Note on Meridian Observations of Nova Persei.

By A. Graham, M.A.

(*Communicated by the Secretaries.*)

The position of *Nova Persei* as deduced from observations with the Cambridge Transit Circle was as follows :—

1901.	App. R.A. h m s	Mean R.A. Jan. 1. h m s	App. Decl. ° ′ ″	Mean Decl. Jan. 1. ° ′ ″
Feb. 25	3 24 29·882	3 24 28·222	43 34 3·85	43 33 54·25
28	29·524	27·934	4·08	54·74
Mar. 1	29·784	28·217	3·40	54·15
2	29·529	27·985	2·93	53·77
3	29·619	28·098	3·06	54·01
5	29·527	28·051	3·70	54·85
7	29·605	28·172	2·53	53·89
12	29·344	28·019	2·88	54·81
21	29·269	28·120	0·78	53·88
Apr. 1	29·114	28·107	43 33 59·59	54·29
	Mean	$3^h\ 24^m\ 28^s{\cdot}092 \pm {}^s{\cdot}065$.		$43°\ 33'\ 54''{\cdot}26 \pm ''{\cdot}27$.

Notes.

February 25. Through clouds. Estimated 1st mag. February 28. Disturbed by knocking at Newall Dome. 2nd mag. March 1. Decidedly red. 2nd mag. March 2. Red. Unsteady. March 3. Through clouds. Faint. March 5. Red. March 7. Through clouds. Very faint. March 12. Considerably fainter. Somewhat less than 3rd mag. March 21. About 4th mag. March 25. Not visible on the meridian in a perfectly clear sky. April 1. Clouds. About 4·5 mag.

The Observatory, Cambridge.

Further Observations of the New Star in Perseus.

By A. Stanley Williams.

The following observations of the brightness of *Nova Persei* are in continuation of those already communicated to the Society and published in *Monthly Notices*, vol. lxi. p. 337. Down to March 18 they were made with the eye aided only by ordinary concave spectacles, but after that date an opera glass was employed. The provisional magnitudes in the last column are, as before, on the H.P. scale, and on the assumption that a step is equivalent to 0·1 mag. It appears to be actually rather smaller

than this, but the determination of the exact value is reserved until the completion of the observations.

Date. 1901.		Greenwich. M.T. h m	Observations.	Mag.
Mar.	5	6 55	*Nova* = β Persei + 5, δ Persei − 7	2·65
	6	7 0	β Persei + 8, δ Persei − 4, γ Persei − 5	2·83
	9	10 0	δ Persei + 2, γ Persei + 1, (ϵ Persei − 5)	3·3
	12	10 30	δ Persei + 2, = γ Persei	3·25
	18	9 50	δ Persei + 10, γ Persei + 9, ν Persei + 2, (ρ Persei − 2)	4·13
	22	10 10	32 Persei + 5, 36 Persei − 3	5·22
	25	9 15	32 Persei + 5, 36 Persei − 1	5·32
	26	10 10	= κ Persei, ν Persei + 5	4·22
		11 45	κ Persei − 3, ν Persei + 4	4·02
	27	10 20	κ Persei − 4, ν Persei + 5	4·02
	28	11 0	κ Persei + 4	4·35
	29	10 15	κ Persei − 2	3·75
	31	10 0	κ Persei + 4 ±	4·35 ±
Apr.	1	10 0	= κ Persei, ν Persei + 6	4·27
	4	10 5	κ Persei − 2, ν Persei + 5	4·12

Notes.

March 5. Very clear. March 6. Clear. March 9. Estimates perhaps not quite unaffected by cloud. March 12. Rather hazy; observations not satisfactory. March 18. Very clear. March 25. Very clear. March 26. Very clear. *Nova* distinctly brighter at $11^h\ 45^m$ than it was at $10^h\ 10^m$. March 27. Slightly hazy, sky very bright. March 28. Clear, but sky bright. March 29. Never quite free from thin cloud, but the *Nova* seemed uniformly a little plainer than κ *Persei*. March 31. Sky never free from thin cloud, but the *Nova* always seemed inferior to κ *Persei*. April 1. Moon very bright, but clear night. April 4. Moon full and sky very bright.

The relative brightness of the comparison stars has seemed in some cases to differ appreciably from what the H.P. values would imply. This is particularly the case with respect to κ and ν *Persei*. The H.P. makes the two stars about equally bright (κ 3·95 and ν 4·00), but on several nights in March ν has seemed to the writer not less than half a magnitude brighter than κ.*

A periodical variation in brightness of *Nova Persei* has recently been announced by von Glasenapp, of St. Petersburg, and Dunér, of Upsala (*A.N.* 3700), minima occurring on March 19,

* This difference may have been due, in part at any rate, to κ being at a slightly lower altitude than ν, and consequently more affected than the latter by atmospheric absorption and the greater brightness of the sky nearer the horizon. But on April 14 at $8^h\ 30^m$ in a very clear sky and with no Moon, κ still seemed distinctly fainter than ν, the difference amounting to three steps.

22, and 25. The above observations show well the faintness of the star on March 22 and 25, whilst there are less marked indications of a decreased brightness on March 28 and 31. It would seem from the latter that either there has been a real diminution in the amplitude of the variation, or else that the period is not exactly three days or uniform in length.

The following notes of the colour of the *Nova* were made with a $2\frac{1}{4}$-inch refractor. March 5, white, certainly no bluish or greenish tinge. March 12, white, with perhaps a slight reddish tinge. March 22, a distinct reddish tinge. March 26, white, with a slight reddish tinge. March 27, colour reddish, the reddish tinge more pronounced than it has been hitherto, though still not so deep and pronounced as the reddish colour of *Mars* or *Aldebaran* to the naked eye. March 28, colour reddish, not very deep. March 29, colour slightly reddish, not at all deep or pronounced. April 1, orange yellow, fairly deep. April 4, orange, not very deep.

It should be mentioned that the colour of this star has seemed to me particularly difficult to describe, there appearing to be distinct flashes of two or more different tints; also that the $2\frac{1}{4}$-inch refractor employed is over-corrected. With the same instrument and power *Algol* appeared distinctly bluish. The *Nova* has always shown a perfectly defined star disc whenever the seeing was good.

Hove: 1901 *March* 8.

Observations of Nova Persei. By M. C. Sharp.

Herewith I forward a table, giving estimated magnitudes of *Nova Persei*, for the most part made with the help of a binocular, except on March 6, 11, and 16, when only a brief glimpse with the naked eye was possible. On these three and some other nights, when moonlight and haze made comparisons difficult, the estimations are marked (?) Indeed, on nights when there was a slight haze or cloud the light of the *Nova* was much more affected than that of neighbouring stars, and in a small telescope it did not seem to have quite the same focus.

The colour at first was a bright orange yellow, as seen with a small refractor of 1·54 in. aperture, but got deeper as the brightness declined. Thus on March 9 and 10 it was pale orange, and a deep orange on the 25th, when it was at its then lowest observed magnitude, while on the 27th it had increased in brightness, and was a light orange yellow. On the 28th it was orange red, and orange yellow again on April 1, when the colour

was next observed. But on the 4th it was once more orange red. That night, however, was rather hazy.

		Est. Mag.			Est. Mag.
Feb.	28	1·6	March	25	5·2
March	1	2·2		27	3·9
	3	2·3		28	4·7
	6	2·8		30	4·3
	9	3·4 (?)		31	4·3
	10	3·3	April	1	4·7
	11	3·6 (?)		4	4·5
	16	3·8 (?)		8	4·7
	23	3·8		10	5·3
	24	4·1			

Highgate, N.: 1901 *April* 11.

Note on some Engraved Charts of Pogson's proposed Atlas of Variable Stars. By J. G. Hagen, S.J.

(*Communicated by the Secretaries.*)

In a former note in the *Monthly Notices* (1898, vol. lix., pp. 57–61) an account was given of Pogson's manuscripts, now preserved at the Harvard College Observatory, which comprise 134 catalogues and eighteen charts for as many variable or temporary stars. From these manuscript charts it was not clear whether they were meant as specimens for the engraver or as the final copies for reproduction. Since then Dr. R. Copeland informed me that the library of the Edinburgh Observatory possessed six engravings of charts which had been printed for Dr. Lee, of Hartwell House, where N. R. Pogson observed in 1859–60, and upon my request kindly forwarded them to me for examination.

The general aspect of these engravings is the same as that of the manuscript charts. They are of the same size, *viz.* about four inches in each dimension, not exactly square-shaped, but tapering, the meridians agreeing with conical projection and the parallels being straight lines. The co-ordinates are drawn at distances of 1^m and $10'$ respectively. The variable on each chart lies a little outside the central cross, because the co-ordinates are absolute, not differential. The epoch of the projection is known to be 1860 from the manuscript catalogues. The inscriptions are in substance the same as in the manuscripts. The star images are rather large, and in many cases accompanied by numbers, whose

meaning would be puzzling did we not know from another source that they are ten times the assumed magnitudes of the stars. The limit of these magnitudes was twelve in the earlier manuscripts, and thirteen in the later ones.

The upper inscriptions of these six engravings are as follows :—

(1)	*Gemini,*	Var. 2,	now known as	2528 *R Geminorum.*
(2)	*Cassiopeia,*	„ 2,	„	8600 *R Cassiopeiæ.*
(3)	*Ursa Major,*	„ 1,	„	3825 *R Ursæ Majoris.*
(4)	„ „	„ 2,	„	4557 *S* „ „
(5)	*Libra*	„ 1,	„	5688 *R Libræ.*
(6)	*Cygnus*	„ 3,	„	7045 *R Cygni.*

Each chart bears below the marks :

N. R. Pogson, Del. J. Basire, Sc.

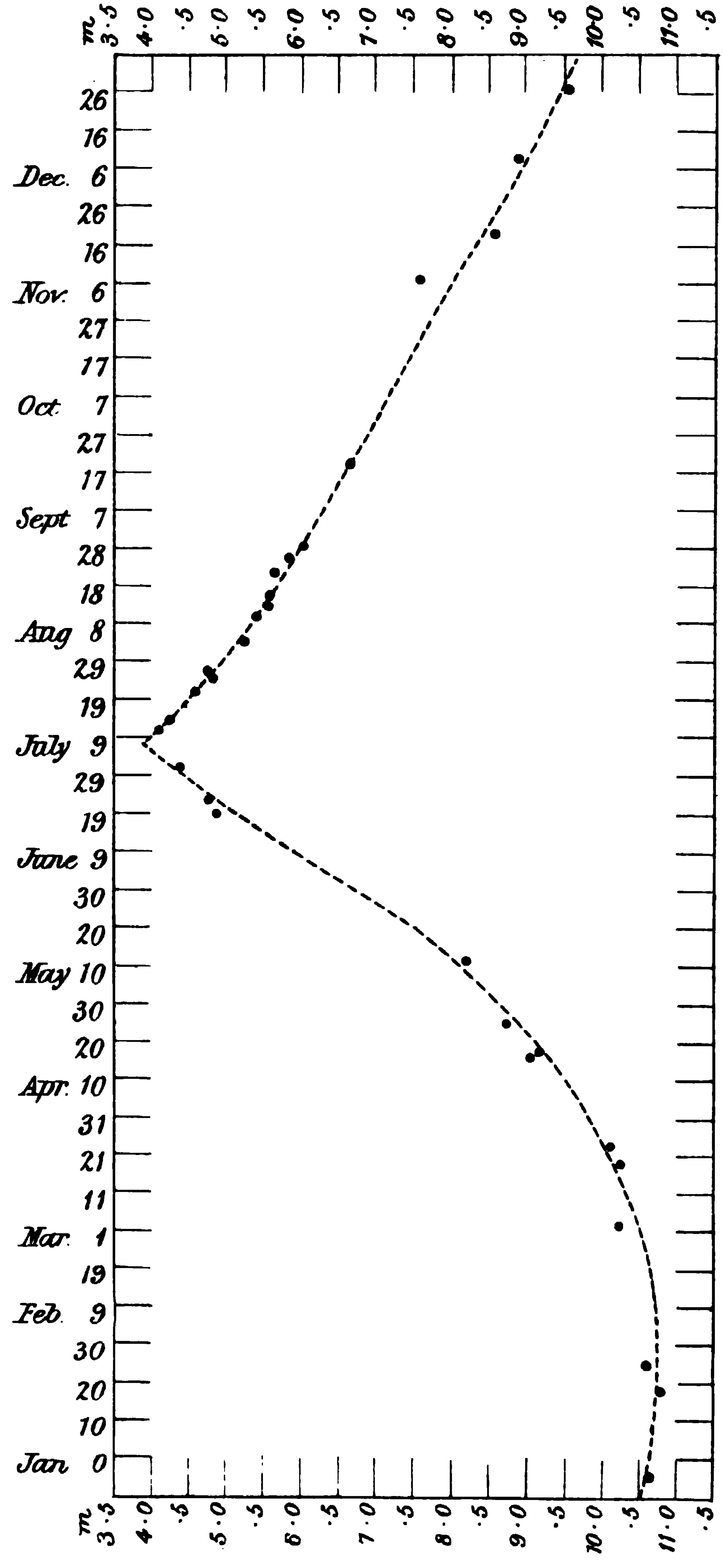
The readers of this note will be interested to learn that three of these charts (Nos. 3, 4, 6) have actually been published, although not recognised as Pogson's charts. They are found in the volume lately issued under the title "Observations of Twenty-three Variable Stars," by the late George Knott, London, 1899 (*Mem. R.A.S.*, vol. lii.), on pages 150, 162, 204. These charts were probably Mr. Knott's own diagrams * and are perfect copies of Pogson's charts, with the exception of the appended notes. From Professor Turner's editorial notes we learn the meaning of those numbers, which might otherwise be taken as catalogue numbers—they are ten times the assumed magnitudes of the stars.

The same three charts, Nos. 3, 4, 6, and also No. 1, allow a comparison with the "Atlas Stellarum Variabilium," in which these same variables occur. The main difference will be found in the area of faintest stars, both as regards extension and density. This area is on Pogson's charts 80′ square, or seven times as large as in the atlas, and only half as dense. If we compare the areas of faint stars which are common to both kinds of charts, namely 30′ square, we find that

for *R Geminorum*,	out of	41	stars in the atlas,	Pogson has	22.
R Ursæ Maj.	„	23	„	„	11.
S „ „	„	11	„	„	8.
R Cygni	„	40	„	„	22.

* The charts 3, 4, 6 in "Observations of Twenty-three Variable Stars" were copied from Pogson's charts, impressions of which had been pasted by Mr. Knott in his ledgers of Variable Stars, now in the Library of the Royal Astronomical Society.—H. H. Turner.

Light Curve of R Horologii during 1900.



In the latter case, however, there are two of the twenty-two of Pogson's stars which are missing in the atlas. The comparison would be quite different for Series IV. (in which *R Cassiopeiæ* occurs) and Series V. of the atlas, which are adapted to variables of brighter minima. It was unfortunate in Pogson's plan of work that it comprehended an area as large as 80′ square for the faintest stars, and that it was applied indiscriminately to variables of bright and faint minima. As a reward for his untiring labour Mr. Pogson had deserved to see his work in print and bear fruit in the hands of others. It is to be hoped that this work may see the light yet in some shape and become useful to the science of variable stars.

Georgetown College Observatory:
1901 *March* 19.

Variation of R Horologii during 1900.
By Alex. W. Roberts, D.Sc.

The variation of this long-period variable during 1900 is so remarkable as to call for special notice.

As a rule the star at a maximum is slightly brighter than the 6th mag., but last year it reached the 4th mag. at its maximum phase.

In the accompanying plate (plate 11) is given the full light curve of the star as obtained from the observations made during 1900. The full period of the star is 408 days, but the portion of the curve on the plate demonstrates sufficiently the form of the light curve.

It will be seen from this curve that the light changes extend over seven magnitudes. This means that at its max. on 1900 July 10 *R Horologii* was at least 650 times brighter than it was at its minimum on 1900 February 2. It would be an advance of more than ordinary importance if we could determine how much hotter *R Horologii* was on 1900 July 10 as compared with 1900 February 2.

Indeed, one is convinced that the secret of long-period variation will be kept until some discovery is made which will enable us to deal with heat rays as we do with light rays.

Lovedale: 1901 *March* 13.

A Method of Mechanically Compensating the Rotation of the Field of a Siderostat. By H. C. Plummer, M.A.

1. The compensation of the rotation of the field of a siderostat, which is necessary for photographic purposes, can be effected doubtless in a great variety of ways. Three methods of achieving this object have been suggested by Professor Turner in the *Monthly Notices* for 1901 January. The third method is particularly elegant; but it is possible, I think, to go still further in the direction of mechanical simplicity. That this is the case I hope the device to be described in this note will make clear.

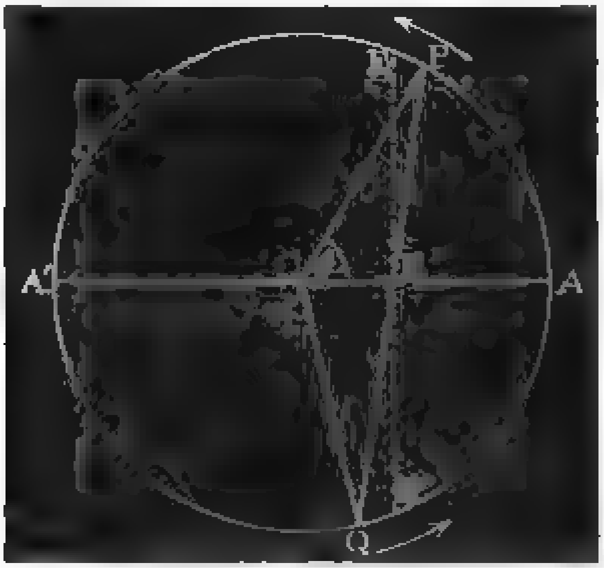


FIG. 1.

2. Let C be the centre of the circle $x^2+y^2=a^2$, and AA′ a diameter. If ACP $= \theta$ and ACQ $= \phi$ (fig. 1), both angles being measured in the same direction, the equation of PQ is

$$x \cos \tfrac{1}{2}(\theta+\phi)+y \sin \tfrac{1}{2}(\theta+\phi)= a \cos \tfrac{1}{2}(\theta-\phi).$$

Hence if PQ cuts AA′ in B, and CB $= b$

$$\frac{b}{a}=\frac{\cos \frac{1}{2}(\theta-\phi)}{\cos \frac{1}{2}(\theta+\phi)}=\frac{1+\tan \frac{1}{2}\theta \tan \frac{1}{2}\phi}{1-\tan \frac{1}{2}\theta \tan \frac{1}{2}\phi}$$

$$\therefore \tan \tfrac{1}{2}\theta \tan \tfrac{1}{2}\phi = -\frac{a-b}{a+b}$$

Let now ACQ $= \phi = \pi + nt$.

$$\therefore \tan \tfrac{1}{2}\theta = \frac{a-b}{a+b} \tan \tfrac{1}{2} nt = \mathrm{K} \tan \tfrac{1}{2} nt$$

if $\dfrac{b}{a}=\dfrac{1-\mathrm{K}}{1+\mathrm{K}}$. But the rotation which is to be compensated is given by the equation

$$\tan \tfrac{1}{2}\theta = \mathrm{K} \tan \tfrac{1}{2} nt$$

where $$K = \frac{\cos \frac{1}{2}(\rho+\delta)}{\cos \frac{1}{2}(\rho-\delta)} = \frac{1-\tan \frac{1}{2}\rho \tan \frac{1}{2}\delta}{1+\tan \frac{1}{2}\rho \tan \frac{1}{2}\delta}$$

or $$\frac{1-K}{1+K} = \tan \tfrac{1}{2}\rho \tan \tfrac{1}{2}\delta$$

Hence it is evident that if $b = a \tan \frac{1}{2}\rho \tan \frac{1}{2}\delta$, and if Q describes the circle uniformly in one day, P also describes the circle in one day, not uniformly, but with exactly the same motion as that of the field of a siderostat set for a star whose N.P.D. is δ. The angle ρ is the angle between the polar axis and the ray reflected in a fixed direction. If the siderostat mirror is placed south of the telescope, the rotation of the field will be in the same direction for all stars which are visible, and the limits of δ are 0 and $\pi-\rho$, and of $\tan \frac{1}{2}\rho \tan \frac{1}{2}\delta$ 0 and 1. That is to say, the limits of b are 0 and a, or B may have any position along the radius CA. The diameter AA′ is in the meridian of the instrument. When the star at the centre of the field is at upper culmination on the instrumental meridian PQ coincides with AA′, and is rotating with minimum velocity. When the same star comes to lower culmination PQ coincides with A′A, and is rotating with maximum velocity.

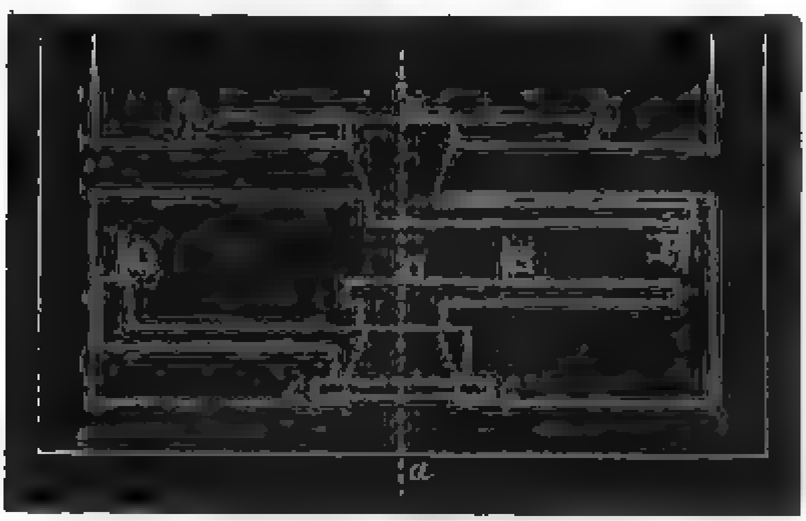


Fig. 2.

3. It is easy to imagine a mechanical arrangement which will satisfy these geometrical conditions. The points P and Q may be represented by two pins mounted on two arms of equal length which are capable of rotating about the same axis. A third bar perpendicular to this axis must be fixed in the meridian of the instrument, and on this we must have the means of accurately adjusting a third pin at a given distance from the axis. This pin serves to fix the position of the point B. A straight slotted bar is pivoted on the pin Q, and passing over the pins B and P keeps the three collinear. Then if the bar carrying Q rotates by clockwork with uniform diurnal motion, that carrying P rotates

in the required manner, and communicates the appropriate motion to the plate-carrier *p a p* (fig. 2), to which it is attached. It is outside my province to discuss here the mechanical details by which the device suggested may best be practically realised. The section in the meridian plane is only given in the hope that it may make a little clearer the practicability of the general method. In this figure *c c* represents the circle to which uniform motion is communicated, but the slotted bar QBP has been omitted.

4. Assuming that a practical design has been found, it is important to study the effect of inaccuracies of adjustment. In setting the pin B we may make an error δb in $b = a \tan \frac{1}{2} \rho \tan \frac{1}{2} \delta$. In the second place the motion may not be correct in phase, that is, the compensating bar PQ may cross the instrumental meridian a small interval of time δt in advance of the star at the centre of the field. When, therefore, the field has turned through an angle θ such that $\tan \frac{1}{2}\theta = \mathrm{K} \tan \frac{1}{2} nt$ the plate has turned through an angle $\theta + \delta\theta$ such that

$$\tan \tfrac{1}{2}(\theta + \delta\theta) = (\mathrm{K} + \delta\mathrm{K}) \tan \tfrac{1}{2} n(t + \delta t)$$

$$\therefore \; \delta\theta = 2\cos^2 \tfrac{1}{2}\theta \{\delta\mathrm{K} \,.\, \tan \tfrac{1}{2} nt + \tfrac{1}{2} \mathrm{K}n \sec^2 \tfrac{1}{2} nt \,.\, \delta t\}$$

$$= \sin\theta \,.\, \frac{\delta\mathrm{K}}{\mathrm{K}} + \frac{n}{\mathrm{K}} \,.\, \frac{\mathrm{K}^2 + \tan^2\frac{1}{2}\theta}{1 + \tan^2\frac{1}{2}\theta} \,.\, \delta t$$

$$= \sin\delta \,.\, \frac{\delta\mathrm{K}}{\mathrm{K}} + \frac{n}{2\mathrm{K}}\{1 + \mathrm{K}^2 - (1 - \mathrm{K}^2)\cos\theta\} \,.\, \delta t.$$

Now
$$\frac{\delta\mathrm{K}}{\mathrm{K}} = -\frac{\delta b}{a-b} - \frac{\delta b}{a+b} = -\frac{2a}{a^2 - b^2} \,.\, \delta b$$

$$\tfrac{1}{2}\left(\frac{1}{\mathrm{K}} + \mathrm{K}\right) = \frac{a^2 + b^2}{a^2 - b^2}$$

$$\tfrac{1}{2}\left(\frac{1}{\mathrm{K}} - \mathrm{K}\right) = \frac{2ab}{a^2 - b^2}$$

Hence
$$\delta\theta = -\frac{2a\sin\theta}{a^2 - b^2} \,.\, \delta b + \frac{n}{a^2 - b^2}(a^2 + b^2 - 2ab\cos\theta)\delta t.$$

5. The actual value of $\delta\theta$ is of little or no consequence, and only concerns the orientation of the picture on the plate. What is of importance is the rate of change of $\delta\theta$. This is

$$\frac{d}{dt}(\delta\theta) = -\frac{2a}{a^2 - b^2}(\cos\theta \,.\, \delta b - b\sin\theta \,.\, n\delta t)\frac{d\theta}{dt}$$

$$= -\frac{2an}{(a^2 - b^2)^2}(a^2 + b^2 - 2ab\cos\theta)(\cos\theta \,.\, \delta b - b\sin\theta \,.\, n\delta t).$$

The critical values of this rate are given by

$$-(a^2 + b^2 - 2ab\cos\theta)(\sin\theta \,.\, \delta b + b\cos\theta \,.\, n\delta t)$$
$$+ 2ab\sin\theta(\cos\theta \,.\, \delta b - b\sin\theta \,.\, n\delta t) = 0$$

or
$$-(a^2+b^2)(\sin\theta\,.\,\delta b+b\cos\theta\,.\,n\delta t)$$
$$+2ab(\sin 2\theta\,.\,\delta b+b\cos 2\theta\,.\,n\delta t)=0$$
i.e.
$$(a^2+b^2)\sin(\theta+a)=2ab\sin(2\theta+a)$$
if
$$\tan a=b\,.\,n\delta t/\delta b$$

If the motion of the arm which carries the pin Q is obtained by gearing it to the hour circle of the siderostat the adjustment of the phase will be automatic. This would be a most convenient arrangement, and ought to minimise the error to be feared from this source. When $\delta t=0$ the critical values of the rate found above will occur at the positions

$$\theta=0,\ \pi,\ \pm\cos^{-1}\frac{a^2+b^2}{4ab}.$$

In one complete rotation the two errors of adjustment will cause a simple oscillation of the field with respect to the plate, of which the amplitude is

$$\frac{4a}{a^2-b^2}\left\{[\delta b]^2+b^2[n\delta t]^2\right\}^{\frac{1}{2}}$$
$$=\frac{2\sin\rho\sin\delta}{\cos\rho+\cos\delta}\left\{\left[\frac{\delta b}{b}\right]^2+[n\delta t]^2\right\}^{\frac{1}{2}}$$
$$=\frac{2\sin\rho}{\cos\rho+\cos\delta}\left\{[\Delta\delta]^2+\sin^2\delta[n\delta t]^2\right\}^{\frac{1}{2}}$$

where $\Delta\delta$ is the error in δ corresponding to the error δb in b. For since $b=a\tan\frac{1}{2}\rho\tan\frac{1}{2}\delta$

$$\delta b/b=\Delta\delta/\sin\delta$$

The fixed bar which carries the pin B will naturally be graduated so as to give the reading of δ directly.

6. When $\delta+\rho=\pi$, $K=0$, and $b=a$; that is to say, in the limit B coincides with A. If the telescope is due north of the siderostat, $\delta+\rho=\pi$ only for a star which culminates on the southern horizon. In the case of a cœlostat the condition is permanent. The representation of the motion of the field given in § 2 illustrates very well Professor Turner's remark on this case. For let EE′ (fig. 1) be the chord perpendicular to the diameter AA′, then P describes the arc E′AE while Q describes the arc EA′E′, and the arc EA′E′ while Q describes E′AE. Now in the limit the arc E′AE vanishes when B coincides with A, and the arc EA′E′ approaches the whole circumference. Hence we see that P coincides with A for twenty-four hours, and then describes the circle with infinite velocity.

7. This interesting example of a change of sign in passing through an infinite value may be considered in another way. We have

$$\frac{d\theta}{dt}=\frac{n}{a^2-b^2}(a^2+b^2-2ab\cos\theta)$$
$$=\frac{n}{2K}\{1+K^2-(1-K^2)\cos\theta\}$$

Hence the hodograph (turned through 90°) of a point rotating with the field may be represented on a scale proportional to K by the curve

$$r = 1 + K^2 - (1 - K^2)\cos\dot{\theta}$$

which is, of course, a limaçon. Since $1 - K^2 < 1 + K^2$, the curve has no node. The vector in the direction $\theta = \pi$ is constant for all values of K. When $K = 1$, the curve is a circle concentric with the pole. When $K = 0$ the hodograph is a cardioide with a cusp at the pole. The parameter is finite, and this evidently corresponds to an infinite angular velocity, because the hodograph has been drawn on a scale proportional to K. In this way we see, not only that the velocity is infinite, but that it is proportional at every point to the radius vector of a cardioide drawn in the same direction.

8. It may not be out of place to add some indication of the way in which this simple device suggested itself. Consider two points describing circles whose radii are r and s, the first with the motion characteristic of the siderostat field, the second uniformly in the same period. Let the motions be projected on a diameter of each circle and let x and y be the projections of the moving radii, so that

$$x = r\cos\theta,\ y = s\cos nt$$

$$\therefore\ \tan^2\tfrac{1}{2}\theta = \frac{r-x}{r+x},\ \tan^2\tfrac{1}{2}nt = \frac{s-y}{s+y}$$

$$\therefore\ (r-x)(s+y) = K^2(s-y)(r+x)$$

$$\therefore\ xy(1-K^2) + sx(1+K^2) - ry(1+K^2) - rs(1-K^2) = 0$$

Hence, if the circles are concentric and the diameters of projection coincident, x and y determine two ranges which are related homographically. If further $s = r$ and the sign of y is changed, the relation becomes

$$xy(1-K^2) - rx(1+K^2) - ry(1+K^2) + r^2(1-K^2) = 0$$

or

$$\left(\frac{x}{r} - \frac{1+K^2}{1-K^2}\right)\left(\frac{y}{r} - \frac{1+K^2}{1-K^2}\right) = \frac{4K^2}{(1-K^2)^2}$$

and the ranges are in involution. The centre of the involution is at a distance $r(1+K^2)/(1-K^2)$ from the centre of the circle and the extremities of the diameter of projection are conjugate points. Hence the construction (fig. 3): Let PMP′, QNQ′ be chords of a circle which are constrained to remain perpendicular to the diameter AA′. The centre of the circle is C, and $CO = r(1+K^2)/(1-K^2)$. Let OMNHK be a Peaucellier linkage, such that AA′ are possible positions of MN. Then if Q describes the circle uniformly in twenty-four hours in the sense

indicated, P will move in the manner required to compensate the rotation of the siderostat field.

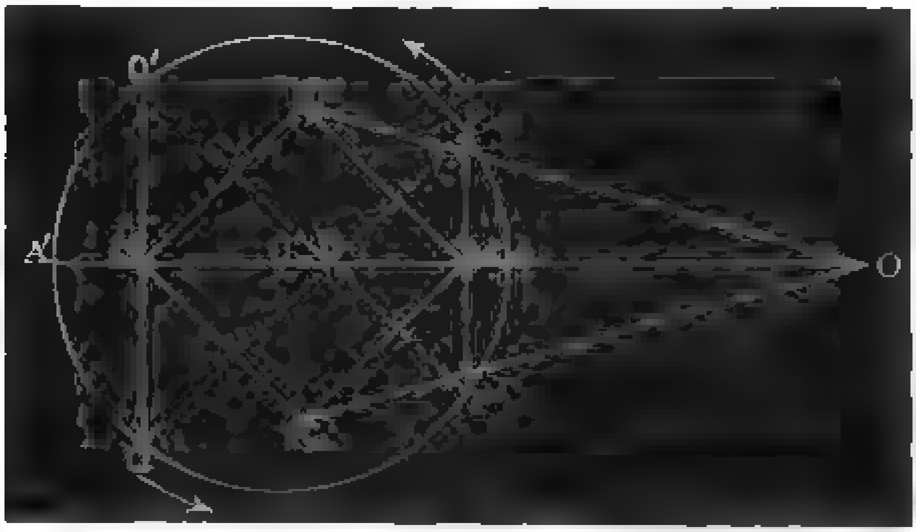


FIG. 3.

9. So far we have derived the motion of P from the rectilinear motions of M and N. The motion of N being simple harmonic, that of M may perhaps be called simple involutional. The method is not a practical one because for fields in the neighbourhood of the pole O is at a very great distance from C. But this method is directly related to the vastly simpler one already given. The parallel chords PP′ and QQ′ are conjugate lines of an involution pencil of which the vertex is at infinity, and the tangents at AA′ are also a conjugate pair. Let PQ, P′Q′ intersect AA′ in the point B. By Desargue's theorem every line intersects the circle and opposite sides of the inscribed quadrangle PP′ QQ′ in an involution range. Hence B is a double point of the involution of which AA′, MN are pairs, and it follows that B is a fixed point for every pair of the involution pencil. Its position is given by the equation

$$x^2(1-K^2)-2rx(1+K^2)+r^2(1-K^2)=0$$

of which the roots are $x=\frac{1-K}{1+K}$ and $x=\frac{1+K}{1-K}$. The former lies within the circle, and is the position determined independently in § 2. The latter is the double point outside, and does not give so convenient a solution of the practical problem. The points PQ, P′Q′, . . . are pairs of an involution range in the circle. This proposition, of which a proof has been given here, can be stated in a more general form. An involution pencil, of which the tangents from the vertex to a conic form a pair, determines an involution range on the conic.

Oxford: 1901 *April* 2.

Further Investigation of the "Two Method" Personal Equation. By Walter W. Bryant.

In a former paper (*Monthly Notices*, 1898 March) I gave an analysis of the results of five years' determinations of the differences of personality between the eye-and-ear and galvanic method for H., A. C., and B., whenever a clock-star was observed by either of them both ways the same night, as part of the routine of the observatory at Greenwich.

The additional evidence since accumulated may throw fresh light upon some of the points then raised.

It may be well to note briefly, as before, that the quantity under discussion is very fairly represented by $t_h + t_c$ for H., who observes galvanically by the "sensorial" method, and by t_h for A. C. and B., who adopt the "muscular" method, t_h being the "reaction to sound," and t_c the time occupied in making a contact, which is theoretically eliminated in the "muscular" method.

Some of the more ordinary causes of variation may be classified as follows :—

A. Personal, the observer's physical, and especially nervous, condition with regard to—

(1) General health, age, &c.

(2) Time of year, time of day, temperature and other external influences.

(3) Comfort at the moment, depending upon observing position (standing, sitting, or reclining), including the inclination of the head with reference to the clock, &c., &c.

B. Impersonal, depending on instruments.

(1) The pricker chronograph is open to the objection that the slight tendency to stop the barrel may introduce a variation in the accuracy of the clock comparison depending upon the fraction of a second between the beats from the two clocks.

(2) Galvanic circuits are liable to vary in resistance, especially at contacts, with heat, cold, damp, &c. ; but this cause is probably insignificant.

(3) From a cause possibly connected with (1) the seconds of Clock Hardy, the transit clock, do not appear to be of the same length, the odd seconds giving a reading differing from that of the even ones.

(4) The force necessary to make a contact varies with the strength of the spring. A new spring tends to make all galvanic observations a little late. If this is delicately adjusted to avoid the difficulty it is found that some

observers make involuntary contacts, which is a far greater evil.

C. Impersonal, depending on—

(1) Optical conditions, brightness of sky, fineness of definition, &c.; also wind, which may affect t_h.

(2) Stellar magnitude, which, however, in the case of clock stars, is not supposed to be so important as for fainter stars.

There is also at times a gratuitous error introduced if the clock comparison is not automatic, which is liable to cancel if not more than cancel t_h, since the dead-beat escapement is not adapted for the "muscular" method of observation (see previous paper for other notes on observing clock).

In the present paper I am only concerned with the effects of A, though C is implicitly involved in A (2).

A (1). One would expect that, as a young observer gains experience, if he adopts the "muscular method" for galvanic observations, his "two-method" P.E. will tend to diminish. But as the effect of age is probably, after a certain time, to slacken mental processes, it seems probable that there is a limit to this diminution, and that at a later period the P.E. will increase.

N.B.—In all that follows suffixes stand for number of single stars observed, and times are given as they were actually observed. I have not reduced any of them to the equator, since neither t_h nor t_e is a function of arc, but only of time, and t_s, the "reaction to light," does not appear in the "two-method" P.E. I have also refrained from loading the observations with varying figures for probable error. Those I have determined vary from $\pm^s{\cdot}04$ to $\pm^s{\cdot}08$ approximately for a well-determined group, but are naturally greater for poor determinations.

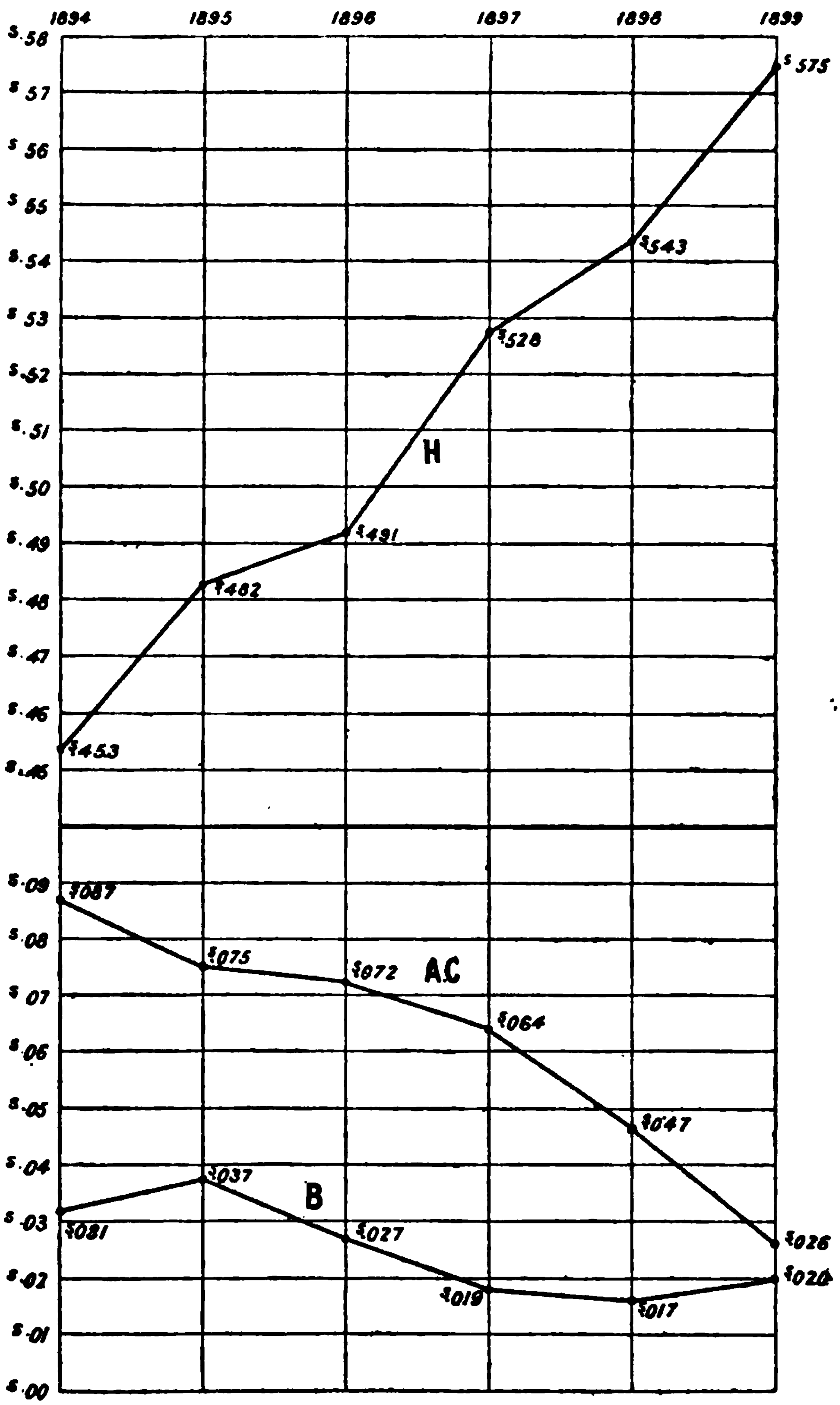
The first table shows annual variation only.

	1893.	1894.	1895.	1896.	1897.	1898.	1899.	1900.
	s	s	s	s	s	s	s	s
H.	$+{\cdot}441_{78}$	$+{\cdot}481_{40}$	$+{\cdot}438_{80}$	$+{\cdot}527_{39}$	$+{\cdot}508_{45}$	$+{\cdot}549_{32}$	$+{\cdot}572_{28}$	$+{\cdot}603_{33}$
A.C.	$+{\cdot}107_{69}$	$+{\cdot}093_{24}$	$+{\cdot}062_{22}$	$+{\cdot}071_{17}$	$+{\cdot}082_{25}$	$+{\cdot}040_{37}$	$+{\cdot}018_{72}$	$+{\cdot}019_{63}$
B.	$-{\cdot}004_{196}$	$+{\cdot}056_{109}$	$+{\cdot}040_{124}$	$+{\cdot}016_{141}$	$+{\cdot}025_{85}$	$+{\cdot}015_{154}$	$+{\cdot}012_{180}$	$+{\cdot}034_{196}$

If we smooth the above by taking means of three consecutive years, the result is striking.

It is unfortunate that the curve for H. cannot be traced back, neither A.C. nor B. having yet reached the standing of H. at the beginning of the series of observations. I am not sure whether to expect a minimum for the "sensorial" method, but if so H. appears to have passed it. In a few years' time the curves for A.C. and B. ought to give a fair test to my experimental theory. B. seems to be inclined to turn back already, but that may be accidental (a new spring, see above, B (4), was fitted in 1900).

It must be remembered in connection with H.'s curve that he is not a "muscular" observer, and so the ascent of the curve may

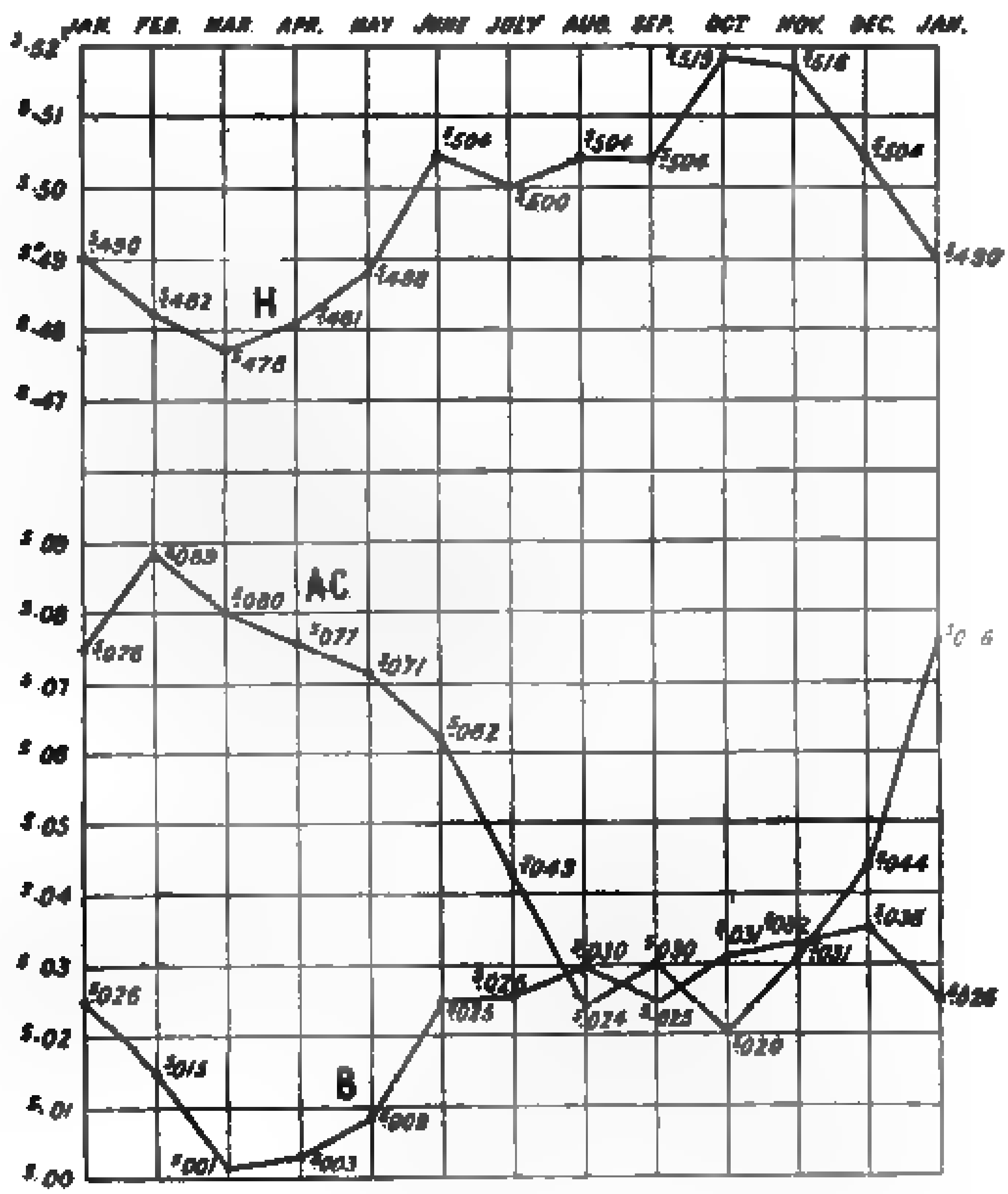


have some other explanation apart from the one suggested above.

A (2). As regards time of year.

	H.	A.C.	B.
	s	s	s
January	$+\cdot493_{22}$	$+\cdot087_{19}$	$+\cdot029_{88}$
February	$+\cdot470_{29}$	$+\cdot095_{20}$	$+\cdot011_{84}$
March	$+\cdot483_{39}$	$+\cdot086_{38}$	$+\cdot006_{112}$
April	$+\cdot481_{40}$	$+\cdot058_{38}$	$-\cdot014_{80}$
May	$+\cdot478_{49}$	$+\cdot087_{39}$	$+\cdot018_{120}$
June	$+\cdot504_{38}$	$+\cdot068_{24}$	$+\cdot024_{80}$
July	$+\cdot530_{28}$	$+\cdot032_{19}$	$+\cdot033_{43}$
August	$+\cdot467_{27}$	$+\cdot030_{24}$	$+\cdot021_{123}$
September	$+\cdot516_{24}$	$+\cdot011_{39}$	$+\cdot035_{127}$
October	$+\cdot529_{31}$	$+\cdot048_{26}$	$+\cdot019_{137}$
November	$+\cdot511_{24}$	$+\cdot001_{19}$	$+\cdot040_{121}$
December	$+\cdot508_{14}$	$+\cdot045_{23}$	$+\cdot038_{63}$

Smoothing as before, three months at a time, we obtain the following results :—



Within limits the curves for H. and B. are similar, with a well-marked minimum in the spring, a maximum towards the end of the year, and a straight piece in the summer.

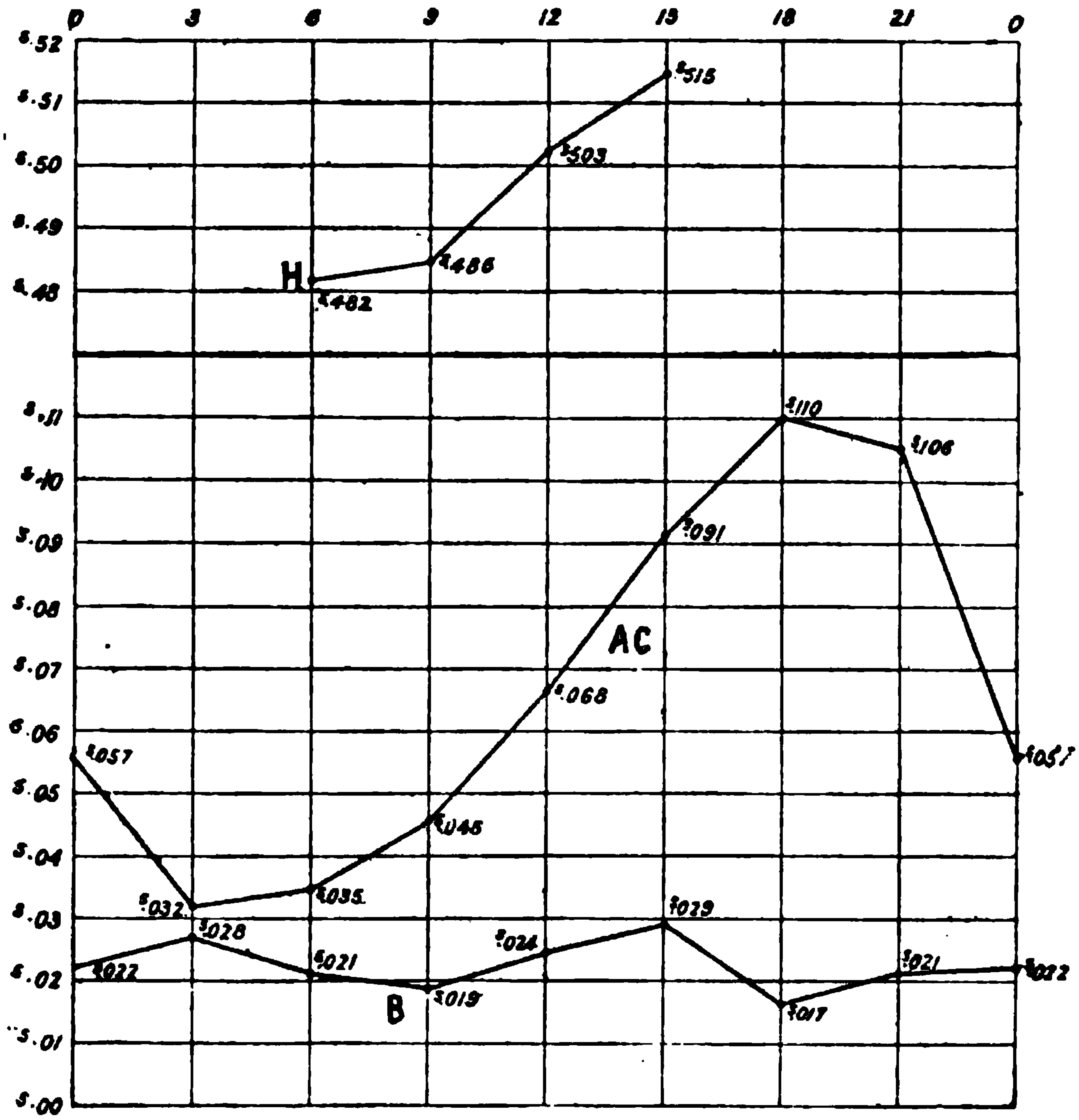
A.C., on the other hand, has a strong minimum in the autumn and a maximum at the beginning of the year.

It is not immediately clear what can be made of these results, but they are interesting even if the weights of the observations are too low to encourage theorising.

Next as regards time of day. Three hour groups.

G.M.T.	H.	A.C.	B.
h	s	s	s
0	—	$+\cdot 058_5$	$+\cdot 057_9$
3	$+\cdot 510_2$	$+\cdot 025_{11}$	$+\cdot 028_{87}$
6	$+\cdot 454_{41}$	$+\cdot 027_{50}$	$+\cdot 014_{298}$
9	$+\cdot 496_{134}$	$+\cdot 054_{126}$	$+\cdot 020_{319}$
12	$+\cdot 506_{164}$	$+\cdot 058_{103}$	$+\cdot 024_{230}$
15	$+\cdot 507_{23}$	$+\cdot 093_{18}$	$+\cdot 027_{38}$
18	$+\cdot 531_{14}$	$+\cdot 123_{12}$	$+\cdot 037_{80}$
21	—	$+\cdot 120_1$	$-\cdot 012_{26}$

All three show a similar effect, possibly due to fatigue, between 6^h and 15^h.



Beyond that there is not the same meaning to the curve, as observations at 18^{h} indicate, not a long duty, but a short special one, denoting Moon about third quarter.

A (3). Dividing the stars into groups of 10° N.P.D.

N.P.D.	H.	A.C.	B.
°	s	s	s
51–61	$+{\cdot}488_{26}$	$+{\cdot}040_{37}$	$+{\cdot}010_{98}$
61–71	$+{\cdot}473_{90}$	$+{\cdot}055_{75}$	$+{\cdot}031_{231}$
71–81	$+{\cdot}481_{75}$	$+{\cdot}073_{67}$	$+{\cdot}020_{280}$
81–91	$+{\cdot}508_{113}$	$+{\cdot}049_{82}$	$+\ 027_{274}$
91–101	$+{\cdot}498_{41}$	$+{\cdot}035_{39}$	$+{\cdot}016_{173}$
101–111	$+{\cdot}547_{28}$	$+{\cdot}071_{16}$	$+{\cdot}013_{94}$
111–121	$+{\cdot}503_{8}$	$+{\cdot}092_{10}$	$+{\cdot}013_{40}$

Here the first three groups correspond fairly well with stars observed in more or less recumbent, and the last three in practically upright position, though for about the middle group, and for five or six degrees each side of it, stars may be observed also kneeling, sitting, or stooping.

A smoothed curve seems therefore out of place, and a rigid line for attitude cannot be drawn either, so that I think the figures should be left to speak for themselves, with the note that $^{s}{\cdot}003$ is greater than the maximum effect of change of distance from observing clock, so that that will not of itself account for the great increase in H. for low stars, and still less will it account for B.'s results. I have investigated the latter more closely for groups of five degrees, three degrees, and one degree (as well as for single hours of G.M.T. in the previous table), and though the results seem too cumbersome and undecided to be worthy of insertion here I may mention that there is a marked maximum at about 70° N.P.D., and that the smallest values appear to belong to the high stars and those below the equator, so that I should conclude that the erect position is the best, but that as the angle of inclination of the head to the direction of the sound of the clock varies, there is a critical angle between the vertical and horizontal, for which the reaction to sound is slowest. An analogous idea was presented to the society by A. W. Roberts as the result of his photometric observations, *i.e.* that there is a critical angle for the sight, two equal sources of light not appearing equal in all positions of the observer.

It seems to me that the part of A (1) which is beyond ordinary investigation, viz. the uncertain condition of the observer's nervous system (or digestion), rendering extended comparisons misleading, is the difficulty which tends most to weaken these results. A long series of experimental observations of this kind is out of the question at Greenwich, the transit circle having a vast amount of work to do, of which these comparisons form but one small item.

Nevertheless I hope in a few years' time to be able to extend this investigation a little further, and to open up one or two fresh lines of research in this psychologically interesting field.

Anomalous Occultations of Stars by the Moon. By R. T. A. Innes.

It is well known that on several occasions double stars have been discovered through the phenomena attending their occultation by the moon.

Cases in point are the discovery by Professor Barnard in 1883 of the duplicity of Bradley 2607, the star which is closely preceding β *Capricorni*, and the discovery by Burg of Vienna in 1819 that *Antares* is a double star.

Another remarkable instance, but not so well known, is that of P. XVI. 68. On 1836 September 16 Sir Thomas Maclear, using a 3-inch telescope, observed the occultation of this star, and remarked that the star "disappeared gradually."

Fifty-three years later Burnham, with the 36-inch Lick refractor, found this to be a double star (β 1115).

In my own experience unusual occultations of many stars have been observed, and some of these were afterwards found to be known pairs, viz.

BD. $-22°$, 3908. "Glided out, took $0^s{\cdot}5$ to disappear." This is β 809, mags. 8·6 and 10·2, distance 1·6″.

P. XIII. 126. "Began to fade at $25^s{\cdot}7$, disappeared at $28^s{\cdot}0$, good." This is β 932, 0·44″.

The slow progression of the moon amongst the stars (about 0·55″ in one second of time) and the sharp character of a good disappearance at the dark limb should similarly disclose the presence of double stars of exceeding closeness, or of stars having a measurable diameter. The greater number of dark-limb occultations are seemingly instantaneous; the exceptions are of two classes:

(A) The star disappears in two distinct stages.

(B) The star disappears gradually, or glides.

When a star disappears in two distinct stages, there is a high presumption that it is really a double star; and at first sight it would appear that the phenomena of "gliding" occurs when a star has a disc of such a size that it is not instantaneously obliterated by the advancing moon. But "gliding" is actually found to occur with double stars, as is shown in the cases of β 809, β 932, and β 1115 quoted above. It may there-

fore be that the difference between "disappearing in two stages" and "gliding" is due to physiological causes. The examples just referred to show that in one case I failed to discriminate between a disappearance in two stages, half a second apart (which is what must actually have occurred) and a "glide"; in the other case the two stages took $2\cdot3^{s}$, and yet they were not seen distinctly, as the word "fade" was adopted. Thus it remains doubtful if there is any real distinction between a star disappearing behind the moon's limb in two stages or in "gliding." If a star has an appreciable diameter it will appear to go out gradually, if the whole time occupied in completing its obscuration is upwards of about $\frac{1}{10}$th of a second. The limit of persistency of retinal impressions is given as from only $\frac{1}{50}$th to $\frac{1}{30}$th of a second—a determination based, I believe, on experiments with electric sparks. In the case of stars it is probable that the limit is longer—perhaps $\frac{1}{10}$th of a second—as has just been assumed. If a star of the ninth magnitude disappears behind the so-called dark limb when the moon is three or four days old, the phenomenon is seldom seen as a sudden one. This may be attributed to the lack of contrast between the star and the strongly illuminated dark limb of the moon, so that the star is only glimpsed by special effort—an effort that cannot be continuously maintained—the interruptions of vision lasting perhaps $\frac{1}{5}$th of a second. If *Sirius* has a real diameter of $0\cdot01''$ its complete occultation would occur in $0\cdot02^{s}$, which would certainly be called "instantaneous." This assumes that the occultation is central. If it occurs at an angle θ from the direction of the moon's path, the time would be

$$\frac{0\cdot02^{s}}{\cos\theta};$$

and this only amounts to $0\cdot1^{s}$ for the few occultations (1 in 50), where θ is greater than $78°$. When θ becomes greater, irregularities of the moon's limb nullify a rigorous application of the formula. It is not probable that any star in the zodiac or elsewhere exceeds *Sirius* in apparent diameter, but it is not impossible. Sometimes, when searching for double stars, one comes across a solitary star which refuses to exhibit the satisfactory hard disc of a single star, but which has not the characteristics of a close double star; there is just a chance that in these rare cases an appreciable disc is really seen. Again, planetary and gaseous nebulæ vary in size from measurable diameters to $1''$ or less, and they no doubt exist in increasing numbers as they become smaller. The star *Lalande* 20204 is really a planetary nebula, but it has often been observed as a star. Another planetary nebula is C.P.D. $-45°$, 7306, and is according to Sir J. Herschel "perfectly sharp, $4''$ in diameter." It is, however, unlikely that there are many unrecorded nebulæ in the guise of bright stars, as gaseous nebulæ are so easily discovered with the spectroscope.

It would thus appear that both the phenomena of disappearing in two stages and of gliding are almost certainly due to the star being really a binary system, but not incontestably so. It is necessary to add that "gliding" is not due to an unsteady atmosphere, as I have frequently secured instantaneous occultations with the very worst definition.

This paper owes its origin to the vivid impression made on my mind when the occultation of *o Tauri* was observed some nights ago (February 26) with the 7-inch Merz refractor of the Cape Observatory. The star disappeared in two equal parts separated by about $0^s{\cdot}2$. The phenomenon was so distinct that I feel quite sure that this star is double. It is difficult to be exact as to the interval of time, which might easily be greater or less than $0^s{\cdot}2$. If it is approximately correct, and the position angle of the double star happens to be parallel to the moon's path, the distance would be about $0''{\cdot}1$. A somewhat similar case with the star τ_1 *Arietis*, wherein two observers at separate stations took part, is recorded in the *B. A. A. Journal*, vol. iii. p. 187.

In the recent lists of Cape occultations published by Sir David Gill many anomalous occultations are recorded; some of the more noticeable which I have observed are :

o Tauri.	As mentioned above.
θ Cancri.	"Disappeared in two stages 0·2 sec. apart as though double, not glided" (1898 April 28).
BD. 15°, 1975.	Mag. 8·0, not so faint as given in B.D., "glided, taking quite 1 sec. to disappear" (1898 May 26).
P. XIV. 212.	A well-known double star with considerable parallax and proper motion. (See *Cape Annals*, vol. viii. p. 105, B.) "The pr. and fainter star glided, the other star disappeared normally" (1898 August 23).
β 709.	"The first and brighter star glided" (1898 December 18).
P. III. 128.	"Some light seemed to disappear some 2 or 3 secs. before the occultation" (1901 January 28).
Arg. + 21°, 526.	"Glided" (Marked "dpl. ?" in *A.G.C.*) (1900 March 6).
δ Scorpii.	"Glided, took $0^s{\cdot}4$ to disappear" (1899 July 18).
P. XI. 77.	"Glided, $0^s{\cdot}3$, greater part of light disappeared suddenly" (1899 May 19).
132 *Tauri.*	"Disappeared in two portions $0^s{\cdot}1$ between, very good observation" (1899 May 12).

A considerable number of the double stars disclosed by occultations will be too close to be confirmed by the telescope, and will therefore form a class intermediate to the visual double and the spectroscopic binary.

The occultations of any spectroscopic binaries within the zodiac should be watched for and widely observed.

A series of occultations of α *Virginis* is now commencing. As α *Virginis* is a well-known spectroscopic binary, these occultations demand special attention.

A point in favour of occultations is that they can be observed very well indeed with telescopes of moderate size.

On some future occasion it is purposed to make a collection of all occultations of the above classes that have been recorded.

Cape of Good Hope: 1901 March 5.

Meteoric Showers from the Region of α–β Persei and η Aurigæ. By W. F. Denning.

A very brilliant meteor was observed at various places in the south of England on 1901 March 6, $7^h\ 25^m$. Descriptions of its appearance and path have been received from Denmead, Hants; Clapham Common, London, and Epsom Common; Isle of Wight; Lewes, Torquay, Yeovil, &c. Several of the observers give the direction of flight as straight from *Nova Persei*, and there is no doubt that the radiant point was at or closely contiguous to $51^\circ+43^\circ$. There is a well-known, long-enduring shower from about 2° W. of this point, and it forms No. XLIII. in the "General Catalogue of Radiants" (*Memoirs R.A.S.*, vol. liii.). At Denmead, Hants, the meteor as it passed under *Orion's* belt appeared like a ball of fire, and from it three small fragments were detached, one being greenish and two, close together, bright red. At Lewes the meteor is described as being magnificently brilliant and of a greenish colour. "It emerged midway between the *Pleiades* and constellation *Perseus*, and after describing a parabola towards the W. it disappeared, leaving a fiery train in its wake." Miss L. M. Milner, of Torquay, says the meteor was directed straight from the new star and fell towards E. through the constellations of *Lynx* and *Leo*. It was orange colour at first, but developed into a brilliant green; then burst into separate green particles and died out. At Yeovil the meteor was seen in *Gemini*, and passed almost vertically downwards. A comparison of the various observations shows that the object fell from about eighty-four to twenty-seven miles above the English Channel fifteen miles south of St. Alban's Head, Dorset, and

St. Catherine's Point, Isle of Wight. The motion was slow, from W. to E., along a path of about sixty-six miles, but these results are only approximate.

A fireball which brilliantly illuminated the sky at several places was seen at Slough, Plymouth, Leicester, &c., on 1900 November 27 11^h 10^m. At the former place Professor A. S. Herschel recorded the apparent path as from $338°+12°$ to $328°+2°$, and the motion was very slow. The radiant point was at about $47°+45°$, and in nearly the same position as that of the fireball of March 6 previously referred to. The height was from fifty-seven to seventeen miles over Ilfracombe and the Bristol Channel.

On 1899 September 2 12^h 5^m a meteor brighter than *Venus* was seen by the writer at Bristol and by Mr. Ivo F. H. C. Gregg at Malvern. The radiant from the pair of observations was at $46°+42°$, and the height of the object eighty-six to sixty miles over Shipston and Tewkesbury, Gloucestershire.

Several other very fine meteors—notably those of 1896 April 12 8^h 6^m and 1894 April 22 7^h 36^m—have diverged from the same position, and Professor Herschel found the radiant of a shooting star recorded on 1865 November 12 at $50°+42°$. Including the latter with seven of my own determinations from duplicate or multiple observations of individual meteors, we have the following list:—

Date.			α δ	
1901	March	6	$51°+43°$	Fireball.
1896	April	12	50+42	„
1894		22	48+44	„
1895	Aug.	7	45+47	Shooting star.
1899		14	52+46	„
1899	Sept.	2	46+42	Fireball.
1865	Nov.	12	50+42	Shooting star.
1900		27	47+45	Fireball.

The mean of these positions is at $48\frac{1}{2}°+44°$.

A brilliant meteor seen at Bristol and Cooper's Hill, Kent, on 1875 March 9, was apparently from the same radiant.

There is a well-defined and tolerably rich shower, or succession of showers, from this centre during the last six months of the year. I have frequently recognised it during the last twenty-five years, and have secured the following independent values for the radiant:—

Date.		α	δ	Meteors.	
		°	°		
1876–87 Feb.	23–Mar. 12	47	+45	5	V. S.
1877 July	20	47	+45	5	R. K.
1884	23–25	48	+43	15	R. K.
1886 Aug.	2–10	48	+43	10	R. K.
1877	3–16	46	+45	6	R. K.
1888–96	5–14	48	+44	6	R. K.
1893	8–16	48	+44	11	R. K.
1899	13–17	47	+44	6	R. K.
1884	19–21	46	+44	4	R. K.
1879	21–23	46	+47	9	R. K.
1900	24–Sept. 2	46	+43	5	R. K.
1887	30	46	+43	4	R. K.
1885 Sept.	15	48	+44	6	R. K.
1877	15–16	47	+45	7	R. K.
1886	22–30	48	+44	6	R. K.
1877 Oct.	3–13	46	+45	14	R.
1887	17–24	47	+44	6	R.
1879	20	45	+46	6	R.
1900	23–27	47	+43	6	S.
1874–99 Nov.	10–15	48	+43	10	S.
1876–87	27–Dec. 8	48	+42	10	S.
1874–88 Dec.	28–Jan. 11	47	+44	7	V. S.

Abbreviations in last column are R. rapid, S. slow, K. streak, V. very.

The average position from the twenty-two radiants is at $47{\cdot}0° + 44{\cdot}1°$, which presents a satisfactory agreement with that derived from the eight doubly observed meteors before alluded to. I believe that, allowing for precession and giving extra weight to the most accurate observations, the centre of radiation of this stream is as nearly as possible $48° + 43\frac{1}{2}°$.

During the thirty-three nights from July 16 to August 17 in various years since 1875 I have recorded sixty-six meteors from this shower, and have seen many others the paths of which were not registered. In July, August, and September the flights are rapid and usually marked with streaks; in October the motion is less rapid, and the streaks are absent. In November and succeeding winter months the meteors travel slowly, and sometimes very slowly, with trains.

The position of the radiant closely W. of *Nova Persei* is interesting, apart from the fact that it has furnished several recent fireballs, and that the shower is apparently one having a very extended duration.

About 20° E. there is another similar radiant (G. C. lxv.) at the star *η Aurigæ* (74°+41°). Professor Herschel and several other observers saw a fine meteor from this centre on 1901 February 13, falling from fifty-six to twenty-six miles over Pembrokeshire. The same apparent radiant gave us the brilliant fireball of 1896 September 10. During the months August to December in various years I noticed this stream on many occasions, and having arranged the observations into groups and reprojected all the paths, find the following radiants :—

Date.		Night.	Radiant. α δ	
Aug.	7–22	16	73° + 41°	16 meteors.
Sept.	12–22	11	74 + 42	28 ,,
	26–Oct. 2	7	73 + 41	15 ,,
Oct.	13–25	13	74 + 41	10 ,,
	31–Nov. 17	18	73 + 42	15 ,,
Nov.	28–Dec. 13	16	74 + 41	10 ,,

The shower is also a conspicuous one, and often yields brilliant fireballs between about February 5–15, though I have myself seen but little of it at that period, having made very few observations in the month of February. From Zezioli's and a number of other meteor-paths observed in Italy in 1869–72 I found a good radiant at 74°+43° (twenty-two meteors) for February 5–10. Greg and Herschel give a radiant at 73°+40° for February 9–17. Schiaparelli found one at 74°+48° from Zezioli's observations on 1868 February 16, and Heis gave 80°+40°, February 16–28. For March 9–27 Greg derived a radiant at 74°+47° from Zezioli's meteors, while on 1865 April 29 Professor Herschel found the radiant of a doubly observed fireball at 75°+47°. This shower of *Aurigids* and that of the *α–β Perseids* deserve special notice on account of their persistency or frequent repetition, and for the very brilliant fireballs which they occasionally discharge. And it is a curious circumstance that the latter sometimes make their apparitions at times when there are few, if any, ordinary shooting stars emanating from the same radiants.

Bishopston, Bristol:
1901 *March* 24.

MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

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DR. J. W. L. GLAISHER, M.A., F.R.S., PRESIDENT, in the Chair;

Jnan Saran Chakravarti, M.A., Assistant Accountant-General, Allahabad, India;
Charles Sidney Mence, 49 Watling Street, London, E.C.;
Rev. John Stutter, O.S.B., Acton Burnell, near Shrewsbury; and
Ernest George Wainwright, B.A., St. John's College, Battersea, S.W.

were balloted for and duly elected Fellows of the Society.

The following Candidates were proposed for election as Fellows of the Society, the names of the proposers from personal knowledge being appended:—

Spencer Lavington Fletcher, 38 Lammas Park Road, Ealing, W. (proposed by Rev. W. J. B. Roome); and
Professor Monroe B. Snyder, Director of the Philadelphia Observatory, Philadelphia, U.S.A. (proposed by Dr. Isaac Roberts).

The following were proposed by the Council as Associates of the Society:—

Professor W. W. Campbell, Director of the Lick Observatory, San José, California, U.S.A.;
Professor Julius Scheiner, Astrophysical Observatory, Potsdam, Germany; and
M. Charles Trépied, Director of the Observatory, Algiers.

Ninety-seven presents were announced as having been received since the last meeting, including, amongst others :—

A 9-inch Newtonian reflecting telescope and other astronomical instruments, formerly belonging to the late Canon Cross, F.R.A.S., presented by Mrs. Cross ; Die Triangulation von Java, Abtheilung VI., edited by J. A. C. Oudemans, presented in the name of the Government of the Netherlands by Professor Oudemans ; A. Laussedat, Recherches sur les instruments, les méthodes et le dessin topographiques, tome 2, presented by the author.

Formulæ and Tables for connecting Coordinates of Stars on Different Photographs, especially Different Plates of the Astrographic Chart. By H. H. Turner, D.Sc., F.R.S., Savilian Professor.

1. If (x_1y_1) are the rectilinear coordinates of a star on one plate, (x_2y_2) those of the same star on another, then generally

$$x_2=\frac{ax_1+by_1+c}{1+kx_1+ly_1},\quad y_2=\frac{dx_1+ey_1+f}{1+kx_1+ly_1}\qquad \dots \quad (1)$$

where a, b, c, d, e, f, k, l are constants for the pair of plates. Of these eight constants k and l are known with sufficient accuracy as the approximate coordinates of one centre referred to the other, and the remaining six may be determined either (1) from the measures themselves directly, or (2) knowing (x_1y_1) in terms of standard coordinates for the first plate $(\xi_1\eta_1)$; also (x_2y_2) similarly in terms of $(\xi_2\eta_2)$ standard coordinates for the second plate ; and finally knowing $(\xi_2\eta_2)$ in terms of $(\xi_1\eta_1)$ from geometrical considerations, we can deduce the values of (x_2y_2) in terms of (x_1y_1).

It is important to be able to use both these methods. The second of them involves three numerical transformations which may be rather laborious ; and the present paper is an attempt to put these transformations into a simple form for the computer.

Mechanical Rule of Procedure.

2. A simple mechanical rule of combining two transformations such as

$$\begin{matrix} X=a_1x+a_2y \\ Y=b_1x+b_2y \end{matrix}\quad \text{with} \quad \begin{matrix} \xi=A_1X+A_2Y \\ \eta=B_1X+B_2Y \end{matrix}$$

has been found useful. The result is of course

$$\xi=(A_1a_1+A_2b_1)x+(A_1a_2+A_2b_2)y=\alpha_1x+\alpha_2y$$
$$\eta=(B_1a_1+B_2b_1)x+(B_1a_2+B_2b_2)y=\beta_1x+\beta_2y$$

and to form a and β by a mechanical process we notice that if we write down the coefficients in determinantal form as follows

$$\begin{vmatrix} a_1 & a_2 \\ b_1 & b_2 \end{vmatrix} \text{ and } \begin{vmatrix} A_1 & A_2 \\ B_1 & B_2 \end{vmatrix}$$

and then multiply the first *row* of the second by the *columns* of the first in turn we get the first *row* of the result, the second row being given by using the second row of the second determinant. If we rewrite the first determinant, substituting columns for rows, we then multiply rows by rows, which helps the eye appreciably.

3. In the work which follows we are often concerned with sets of coefficients which are conveniently written as follows :—

$$\begin{vmatrix} 1+a_1 & a_2 \\ b_1 & 1+b_2 \end{vmatrix} \text{ and } \begin{vmatrix} 1+A_1 & A_2 \\ B_1 & 1+B_2 \end{vmatrix}$$

all the letters denoting small quantities. In such cases the result takes a particular form which is worthy of note. If we omit unity in the terms of the leading diagonal we get the determinants of the last paragraph, and if we multiply these as before, and add to each term both of the corresponding terms of the factors, and finally replace unity in the leading diagonal, we get the result required for the expressions of the present paragraph.

Thus the first term is

$$1+(a_1+A_1)+(A_1a_1+A_2b_1)$$

where $(A_1a_1+A_2b_1)$ represents the term as it would be formed if the factors were as in § 2 ; a_1+A_1 is the sum of the first terms of the two factors ; and unity is added because the term occurs in the diagonal.

The rule is simpler in practice than in statement, as will be found on trial.

4. Both of the preceding paragraphs, though stated, for simplicity's sake, for determinants of four terms only, hold for any number of terms. As a numerical example suppose

$$\left.\begin{aligned} \xi_1 &= (1-{\cdot}00767)x_1 - {\cdot}00841y_1 + {\cdot}0833 \\ \eta_1 &= +{\cdot}00852x_1 + (1-{\cdot}00755)y_1 + {\cdot}2285 \end{aligned}\right\} \quad \dots \quad (2)$$

and also

$$\left.\begin{aligned} \xi_2 &= (1-{\cdot}00003)\xi_1 + {\cdot}00751\eta_1 - 10{\cdot}8766 \\ \eta_2 &= -{\cdot}00751\xi_1 + (1-{\cdot}00003)\eta_1 - 11{\cdot}9594 \end{aligned}\right\} \quad \dots \quad (3)$$

and we wish to find $(\xi_2\eta_2)$ in terms of (x_1y_1). We have only two variables in each case, but three terms in each equation. We complete each set by adding unity as a third variable, writing under the equations (2)

$$1=0 \, . \, x_1+0 \, . \, y_1+1\times 1$$

so that the determinant for expressing $(\xi_1 \eta_1 1)$ in terms of $(x_1 y_1 1)$ is (omitting unity in the diagonal)

$$\begin{vmatrix} -\cdot00767 & -\cdot00841 & +\ \cdot0833 \\ +\cdot00852 & -\cdot00755 & +\ \cdot2285 \\ 0 & 0 & 0 \end{vmatrix} \quad \ldots \quad (4)$$

and that for expressing $(\xi_2 \eta_2 1)$ in terms of $(\xi_1 \eta_1 1)$ is

$$\begin{vmatrix} -\cdot00003 & +\cdot00751 & -10\cdot8766 \\ -\cdot00751 & -\cdot00003 & -11\cdot9594 \\ 0 & 0 & 0 \end{vmatrix} \quad \ldots \quad (5)$$

To find that for $(\xi_2 \eta_2 1)$ in terms of $(x_1 y_1 1)$ we first form the products of these as they stand, thus:

$$\begin{aligned} -\cdot00003 \times (-\cdot00767) + \cdot00751 \times (+\cdot00852) + 0 &= +\cdot00006 \\ -\cdot00003 \times (-\cdot00841) + \cdot00751 \times (-\cdot00755) + 0 &= -\cdot00006 \\ -\cdot00003 \times (+\ \cdot0833) + \cdot00751 \times (+\ \cdot2285) + 0 &= +\ \cdot0016 \end{aligned}$$

and so on. The result is

$$\begin{vmatrix} +\cdot00006 & -\cdot00006 & +\ \cdot0016 \\ +\cdot00006 & +\cdot00006 & -\ \cdot0006 \\ 0 & 0 & 0 \end{vmatrix} \quad \ldots \quad (6)$$

Now add the corresponding terms in (4), (5), and (6), and replace unity in the diagonal. We get for our result

$$\begin{vmatrix} 1-\cdot00764 & -\cdot00096 & -10\cdot7917 \\ +\cdot00107 & 1-\cdot00752 & -11\cdot7315 \\ 0 & 0 & 1 \end{vmatrix} \quad \ldots \quad (7)$$

which means that

$$\left.\begin{aligned} \xi_2 &= (1-\cdot00764)x_1 - \cdot00096 y_1 - 10\cdot7917 \\ \eta_2 &= \ \ +\cdot00107 x_1 + (1-\cdot00752) y_1 - 11\cdot7315 \end{aligned}\right\} \quad \ldots \quad (8)$$

The arrangement of the work can be varied a little according to individual taste or according to the quantities involved.

5. The rules are equally convenient in algebraical transformations, of which some examples follow. Before giving them attention may be called to a particular case.

Let three direction-cosines $(l\ m\ n)$ be given in terms of $(\lambda\ \mu\ \nu)$ by the equations

$$\left.\begin{aligned} l &= a_1\lambda + a_2\mu + a_3\nu \\ m &= b_1\lambda + b_2\mu + b_3\nu \\ n &= c_1\lambda + c_2\mu + c_3\nu \end{aligned}\right\} \quad \ldots \quad \ldots \quad \ldots \quad (9)$$

and let three others (L, M, N) be given also in *terms of the same* $(\lambda\,\mu\,\nu)$ by equations with capital letters for the coefficients.

$$L = A_1\lambda + A_2\mu + A_3\nu \text{ \&c.} \quad \ldots \quad \ldots \quad \ldots \quad (10)$$

and suppose we wish to find (L M N) in terms of $(l\,m\,n)$ by eliminating $(\lambda\,\mu\,\nu)$. This is not the same as the operation already considered; but we can make it the same by inverting equations (9) so as to get $(\lambda\,\mu\,\nu)$ in terms of $(l\,m\,n)$. Now by the properties of direction-cosines we do this by writing the coefficients $a_1\,b_1\,c_1$, which occur in the first *column* of (9), as the first *row* of the new equations; *i.e.*

$$\lambda = a_1 l + b_1 m + c_1 n \text{ \&c.} \quad \ldots \quad \ldots \quad \ldots \quad (11)$$

and now, according to our rule, to get (L M N) in terms of $(l\,m\,n)$ we multiply the rows of $\begin{vmatrix} A_1A_2A_3 \\ B_1B_2B_3 \\ C_1C_2C_3 \end{vmatrix}$ by the columns of $\begin{vmatrix} a_1b_1c_1 \\ a_2b_2c_2 \\ a_3b_3c_3 \end{vmatrix}$; or if we keep this latter in its original form (without changing rows for columns) we multiply *rows* by *rows*. Thus to eliminate $(\lambda\,\mu\,\nu)$ from two sets of equations like (9) and (10) *when the variables are direction-cosines* we multiply rows by rows as they stand; so that

$$L = \alpha_1 l + \alpha_2 m + \alpha_3 n \text{ \&c.}$$

where
$$\left.\begin{aligned} \alpha_1 &= A_1a_1 + A_2a_2 + A_3a_3 \\ \alpha_2 &= A_1b_1 + A_2b_2 + A_3b_3 \end{aligned}\right\} \text{\&c.}$$

6. We proceed to consider the relations between standard coordinates on two different plates. The problem has been treated before (see *Monthly Notices*, liv. pp. 20 and 573), but the method indicated in the preceding paragraphs allows us to arrive at practical formulæ much more easily. We begin with direction-cosines as suggested in a former paper (*Monthly Notices*, lx. p. 201).

Let L M N represent the particular system

$$L = \sin\alpha\cos\delta \quad M = -\cos\alpha\cos\delta \quad N = \sin\delta$$

so that standard coordinates (ξ, η) on a plate with its centre at the pole are

$$\xi = L/N \qquad \eta = M/N$$

assuming that ξ and η are expressed in *circular measure*.

7. We now find (l, m, n) the coordinates referred to a plate-centre (A, D) in two steps.

First rotate the axis through an angle A round the axis of N so as to get

$$\left.\begin{array}{l} X = L\cos A + M\sin A \\ Y = -L\sin A + M\cos A \\ Z = N \end{array}\right\} \quad \dots \quad \dots \quad (12)$$

and next rotate round the axis of X through an angle $90°-D$, getting

$$\left.\begin{array}{l} l = X \\ m = Y\sin D + Z\cos D \\ n = -Y\cos D + Z\sin D \end{array}\right\} \quad \dots \quad \dots \quad (13)$$

Eliminating (X Y Z) in the manner indicated, the determinant for expressing (l, m, n) in terms of (L M N) is

$$\begin{vmatrix} \cos A & \sin A & 0 \\ -\sin A\sin D & \cos A\sin D & \cos D \\ \sin A\cos D & -\cos A\cos D & \sin D \end{vmatrix} \quad \dots \quad (14)$$

For clearness it may be remarked that $(l\ m\ n)$ are such that the standard coordinates referred to a plate-centre whose R.A. is A and declination D are

$$\xi = l/n \qquad \eta = m/n$$

8. Now let $(l_1\, m_1\, n_1)$ refer to a plate-centre (A, D_1) and $(l_2\, m_2\, n_2)$ to a plate-centre (A, D_2) with the same R.A., but differing in declination. Then $(l_1\, m_1\, n_1)$ and $(l_2\, m_2\, n_2)$ are both given in terms of (L M N) by determinants like (14), writing D_1 and D_2 respectively in place of D. To eliminate (L M N) and find $(l_2\, m_2\, n_2)$ in terms of $(l_1\, m_1\, n_1)$ we use the rule of § 5, multiplying rows by rows as they stand. The result is

$$\begin{vmatrix} 1 & 0 & 0 \\ 0 & +\cos(D_2-D_1) & -\sin(D_2-D_1) \\ 0 & +\sin(D_2-D_1) & +\cos(D_2-D_1) \end{vmatrix} \quad \dots \quad (15)$$

which is independent of A and D and depends on the difference (D_2-D_1) simply. For the plates of the Astrographic Chart this is always either 1° or 2°, the overlap in the second case being small. If we put $\tau = \tan(D_2-D_1)$, then

$$\sec(D_2-D_1) = (1+\tau^2)^{\frac{1}{2}} = 1 + \tfrac{1}{2}\tau^2 - \tfrac{1}{8}\tau^4 + \&c.$$

If $\tau = \tan 1° = \cdot 0174550$, $\frac{1}{8}\tau^4 = \cdot 00000001 = 0''\cdot 002$ and may be neglected. If $\tau = \tan 2°$, $\frac{1}{8}\tau^4 = 0''\cdot 03$ and can usually be neglected. For the present we shall assume that fourth powers can be neglected.

9. Since ξ and η are only concerned with the *ratios* of l and m to n, we may divide out by any common factor, such as $\cos(D_2-D_1)$, and thus (15) takes the form

$$\begin{vmatrix} 1+\frac{1}{2}\tau^2 & 0 & 0 \\ 0 & 1 & -\tau \\ 0 & \tau & 1 \end{vmatrix} \qquad \ldots \qquad \ldots \qquad (16)$$

10. Next let us change the R.A. of the plate-centre without changing the declination; *i.e.* we have to multiply two determinants such as (14), in which first A_1 and secondly A_2 is substituted for A. The result is, writing a for A_2-A_1

$$\begin{vmatrix} \cos a & \sin D \sin a & -\cos D \sin a \\ -\sin D \sin a & \cos^2 D+\sin^2 D\cos a & \sin D\cos D\,(1-\cos a) \\ \cos D\sin a & \sin D\cos D(1-\cos a) & \sin^2 D+\cos^2 D\cos a \end{vmatrix} \quad (17)$$

11. Put $\sin a \cos D=\gamma$. Then γ is always small, for when D becomes large, A_2-A_1 or a increases approximately as sec D. For the plates of the astrographic chart γ is kept as nearly as possible at 1° (or 2°) and is of the same order as τ in the preceding paragraph. But if we write $t=\tan D$, then $\sin(A_2-A_1)\sin D=\gamma t$, and may become large.

Now,

$$1-\cos a=2\sin^2\frac{a}{2}=\tfrac{1}{2}\gamma^2\sec^2 D\sec^2\frac{a}{2}$$
$$=\tfrac{1}{2}\gamma^2(1+t^2)+\tfrac{1}{8}\gamma^4(1+t^2)^2+\text{ \&c.}$$

The first term is sufficient except near the Pole. The value of the second term at various values of D is as follows, assuming $\gamma=\tan 1°$:

D=	40°	45°	50°	55°	60°
Value=	0''·007	0''·009	0''·013	0''·020	0''·035

For the present we will neglect the second term; and we must remember that the following formulæ are not accurate beyond D=60°.

12. With this restriction (17) may be written:

$$\begin{vmatrix} 1-\frac{1}{2}\gamma^2(1+t^2) & +\gamma t & -\gamma \\ -\gamma t & 1-\frac{1}{2}\gamma^2 t^2 & +\frac{1}{2}\gamma^2 t \\ +\gamma & +\frac{1}{2}\gamma^2 t & 1-\frac{1}{2}\gamma^2 \end{vmatrix} \quad . \quad . \quad (18)$$

As before we may divide out by $1-\frac{1}{2}\gamma^2$; and it seems an obvious simplification to write a single symbol for $\gamma/(1-\frac{1}{2}\gamma^2)$. But experience shows that nothing is ultimately gained by this.

Indeed, we have already made a false step as regards ultimate simplicity. Instead of writing

$$\gamma=\sin\,(A_2-A_1)\cos D$$

it will be found better to have

$$\beta=(A_2-A_1)\cos D$$

so that β is directly proportional to the difference of R.A. of the centres. Making this substitution so that

$$\gamma=\beta-\tfrac{1}{6}\beta^3(t^2+1)$$

the determinant (18) becomes

$$\begin{vmatrix} 1-\frac{1}{2}\beta^2t^2 & \beta t & -\beta-\frac{1}{3}\beta^3+\frac{1}{6}\beta^3t^2 \\ -\beta t & 1-\frac{1}{2}\beta^2(t^2-1) & \frac{1}{2}\beta^2 t \\ \beta & 0 & 1 \end{vmatrix} \quad . \quad (19)$$

in which, however, some terms have been neglected, viz. the last column which multiplies n (which is near unity) is correct to the third power of β; but in the first two which multiply the small quantities (l and m or ultimately ξ and η) cubes of β have been neglected; and in the last line of these two columns, which ultimately multiplies squares of ξ and η, only the first powers are retained.

13. Let us now combine the two operations. We may move the centre first in R.A. and then in declination, or *vice versâ.* In the first case β will denote $(A_2-A_1)\cos D_1$, and in the second case $(A_2-A_1)\cos D_2$. On trial the formulæ are a little simpler in the first case; and we therefore move the centre

First in R.A. as in (19)
Next in decl. as in (16)

so that β denotes $(A_2-A_1)\cos D_1$.

Combining (19) and (16) as before we find, neglecting *squares* of β and τ in the first two terms of third row, *cubes* in first two terms of first and second rows, and fourth powers in the last column:

$$\begin{vmatrix} 1+\frac{1}{2}(\tau^2-\beta^2t^2), & \beta t, & -\beta-\frac{1}{3}\beta^3+\frac{1}{6}\beta^3t^2-\frac{1}{2}\beta\tau^2 \\ -\beta(t+\tau), & 1-\frac{1}{2}\beta^2(t^2-1), & -\tau+\frac{1}{2}\beta^2 t \\ \beta & \tau & 1 \end{vmatrix} \quad (20)$$

The term at the right-hand bottom corner is really $1+\frac{1}{2}\beta^2\tau t$; but on dividing by this factor throughout no terms are introduced of the order to be retained.

This gives the relations between $(l_2\ m_2\ n_2)$ and $(l_1\ m_1\ n_1)$; or

if $\xi\eta$ denote standard coordinates *expressed in circular measure* so that

$$\xi = l/n \qquad \eta = m/n$$

or

$$l = n\xi \qquad m = n\eta \qquad n = n \times 1$$

then since we are ultimately concerned with ratios only, we may omit the common factor n, and the above determinant gives the relations between $(\xi_2\ \eta_2\ 1)$ and $(\xi_1\ \eta_1\ 1)$.

14. But in practice we should not compare $(\xi_2\ \eta_2\ 1)$ with $(\xi_1\ \eta_1\ 1)$ as they stand. We should first add to one set the small terms representing the effect of the denominator. Writing the relations

$$\xi_2 = \frac{(1+a)\xi_1 + b\eta_1 + c}{1 + k\xi_1 + l\eta_1} \qquad \eta_2 = \frac{d\xi_1 + (1+e)_1 + f}{1 + k\xi_1 + l\eta_1} \quad \dots \quad (21)$$

[where $a = \frac{1}{2}(\tau^2 - \beta^2 t^2)$, $b = \beta(t - \tau)$, &c., in (16)]

we can rewrite the first of these

$$\xi_2 + k\xi_1\xi_2 + l\eta_1\xi_2 = (1+a)\xi_1 + b\eta_1 + c \quad \dots \quad \dots \quad (22)$$

The terms added to ξ_2 on the left are small, and we may in them put with sufficient accuracy

$$\xi_2 = \xi_1 + c \qquad \eta_2 = \eta_1 + f$$

It is shown in a former paper (*Monthly Notices*, lv. p. 108) that the most convenient way to apply these small terms to $(\xi_2\eta_2)$ is to move the origin (for them only) to the point midway between the two plate-centres, *i.e.* the point

$$\xi_1 = -\tfrac{1}{2}c \qquad \eta_1 = -\tfrac{1}{2}f$$

Thus we put $k\xi_1(\xi_1 + c) + l\eta_1(\xi_1 + c)$ into the form

$$\left.\begin{array}{l} k(\xi_1 + \frac{1}{2}c)^2 + l(\eta_1 + \frac{1}{2}f)(\xi_1 + \frac{1}{2}c) \\ -\frac{1}{4}kc^2 - \frac{1}{4}lcf - \frac{1}{2}lf\xi_1 + \frac{1}{2}lc\eta_1 \end{array}\right\} \quad \dots \quad \dots \quad (23)$$

of which the second line, containing only linear terms, can be added to the right-hand side of equation (22). Or writing

$$\left.\begin{array}{l} P = k(\xi_1 + \frac{1}{2}c)^2 + l(\eta_1 + \frac{1}{2}f)(\xi_1 + \frac{1}{2}c) \\ Q = k(\xi_1 + \frac{1}{2}c)(\eta_1 + \frac{1}{2}f) + l(\eta_1 + \frac{1}{2}f)^2 \end{array}\right\} \quad \dots \quad (24)$$

we have

$$\left.\begin{array}{l} \xi_2 + P = (1 + a + \frac{1}{2}lf)\xi_1 + (b - \frac{1}{2}lc)\eta_1 + c + \frac{1}{4}kc^2 + \frac{1}{4}lcf \\ \eta_2 + Q = (d - \frac{1}{2}kf)\xi_1 + (1 + e + \frac{1}{2}kc)\eta_1 + f + \frac{1}{4}lf^2 + \frac{1}{4}kcf \end{array}\right\} \quad (25)$$

In the paper above referred to it is shown that the corrections P and Q are sensibly zero over a large part of the re ion common to the two plates, and only reach $1''\!\cdot\!0$ in the cor. ers of this region. They are easily applied, from approximate values of the coordinates, by means of a small table or a diagram.

15. Returning now to (20) and (24) we see that we may put

$$c=-\beta \qquad f=-\tau \qquad k=\beta \qquad l=\tau$$

and thus

$$\left.\begin{aligned} P&=+\beta(\xi_1-\tfrac{1}{2}\beta)^2+\tau(\xi_1-\tfrac{1}{2}\beta)(\eta_1-\tfrac{1}{2}\tau) \\ Q&=+\beta(\xi_1-\tfrac{1}{2}\beta)(\eta_1-\tfrac{1}{2}\tau)+\tau(\eta_1-\tfrac{1}{2}\tau)^2 \end{aligned}\right\} \quad \ldots \quad (26)$$

and substituting the values of a, b, c, &c., we find for ξ_2+P, η_2+Q in terms of $(\xi_1\eta_1)$, the determinant (instead of (20))

$$\begin{vmatrix} 1-\frac{1}{2}\beta^2t^2, & \beta(t+\frac{1}{2}\tau), & -\beta-\frac{1}{12}\beta^3+\frac{1}{6}\beta^3t^2-\frac{1}{4}\beta\tau^2 \\ -\beta(t+\frac{1}{2}\tau), & 1-\frac{1}{2}\beta^2t^2, & -\tau+\frac{1}{2}\beta^2t+\frac{1}{4}\tau^3+\frac{1}{4}\beta^2\tau \\ 0 & 0 & 1 \end{vmatrix} \quad (27)$$

16. The expressions in the third column differ from β and τ by small quantities of which $-\frac{1}{2}\beta^2t$ alone is of the second order. Had we taken the circular measure of 1° for τ instead of the tangent, we should have had instead of $\frac{1}{4}\tau^3$

$$\tfrac{1}{4}\tau^3-\tfrac{1}{3}\tau^3=-\tfrac{1}{12}\tau^3$$

as in the case of β. These expressions lend themselves readily to tabulation for different values of β and τ; for if we calculate the values of (say)

$$-\beta,\ -\tfrac{1}{4}\beta\tau^2, \text{ and } +\tfrac{1}{6}\beta^3(t^2-\tfrac{1}{2})$$

for $\beta=1^{\text{min}}$, $\tau=1°$, then to get the values for $\beta=m^{\text{min}}$, $\tau=n°$, we multiply these terms by m, mn, and m^3 respectively.

17. But the most important feature of the determinant (27) is the form of the four terms in the top left corner. If we put

$$\sin\theta=\beta(t+\tfrac{1}{2}\tau)$$

then to the order of approximation named we have

$$\cos\theta=1-\tfrac{1}{2}\beta^2t^2$$

so that the determinant may be written

$$\begin{vmatrix} \cos\theta & \sin\theta & -C \\ -\sin\theta & \cos\theta & -F \\ 0 & 0 & 1 \end{vmatrix} \quad \ldots \quad \ldots \quad (28)$$

or otherwise

$$\left.\begin{aligned} \xi_2+P&=\ \ \xi_1\cos\theta+\eta_1\sin\theta-C \\ \eta_2+Q&=-\xi_1\sin\theta+\eta_1\cos\theta-F \end{aligned}\right\} \quad \ldots \quad \ldots \quad (29)$$

so that ξ_2+P, η_2+Q can be obtained from $(\xi_1\eta_1)$ by rotation of the axes through an angle θ and a change of origin. This is not only interesting theoretically but is an important practical gain, since we have only two quantities ($\sin\theta$ and $\cos\theta$) to tabulate instead of four, as in (20). [We might indeed say that we

have only one, viz. the argument θ; but it will be more convenient for the computer to have $\sin\theta$ and $\cos\theta$ given him.] This proposition has only been proved in an approximate form at present; but it is accurately and generally true, as will now be shown by an independent proof.

18. Suppose we have in the general case

$$X=\frac{a_1x+a_2y+a_3}{c_1x+c_2y+c_3} \qquad Y=\frac{b_1x+b_2y+b_3}{c_1x+c_2y+c_3} \quad \dots \quad (30)$$

where $a_1a_2a_3$, $b_1b_2b_3$, $c_1c_2c_3$ are a set of direction cosines with the well known properties

$$a_1=b_2c_3-b_3c_2, \qquad b_1=a_3c_2-a_2c_3 \text{ \&c.}$$
$$a_1^2+a_2^2+a_3^2=1, \qquad a_1a_2+b_1b_2+c_1c_2=0 \text{ \&c.}$$

Then

$$c_3X+X(c_1x+c_2y)=a_1x+a_2y+a_3 \quad \dots \quad \dots \quad (31)$$

In the products $X(c_1x+c_2y)$ let us move the origins of coordinates through distances to be presently determined.

Thus write

$$X(c_1x+c_2y)=(X-k)\{c_1(x-a)+c_2(y-\beta)\}$$
$$+X(c_1a+c_2\beta)+k\{c_1x+c_2y-c_1a-c_2\beta\} \quad \dots \quad (32)$$

Denoting $(X-k)\{c_1(x-a)+c_2(y-\beta)\}$ by P we have on combining (31) and (32)

$$(c_3+c_1a+c_2\beta)X+P=(a_1-kc_1)x+(a_2-kc_2)y+a_3$$
$$+kc_1a+kc_2\beta \quad \dots \quad (33)$$

Similarly

$$(c_3+c_1a+c_2\beta)Y+Q=(b_1-lc_1)x+(b_2-lc_2)y+b_3+lc_1a+lc_2\beta \quad (34)$$

We have in these equations moved the origin of (X, Y) in the small terms P and Q to the point (k, l) and the origin of (x, y) to the point (a, β).

19. Now if the transformations on the right of (33) and (34) represent a rotation (with possible change of scale also) we have

$$\left.\begin{aligned} a_1-kc_1&=b_2-lc_2 \\ \text{and} \qquad a_2-kc_2+b_1-lc_1&=0 \end{aligned}\right\} \dots \quad \dots \quad \dots \quad (35)$$

These equations give

$$k=\frac{a_1c_1-b_2c_1+a_2c_2+b_1c_2}{c_1^2+c_2^2}=\frac{-a_3c_3+a_3}{1-c_3^2}$$

$$\left.\begin{aligned} \text{or} \qquad k&=\frac{a_3}{1+c_3} \\ \text{and} \qquad l&=\frac{b_3}{1+c_3} \text{ similarly} \end{aligned}\right\} \quad \dots \quad \dots \quad (36)$$

The amount of rotation θ is given by

$$\sin\theta = a_2 - kc_2 = -(b_1 - lc_1) = \frac{a_2 - b_1}{1 + c_3} \quad \dots \quad \dots \quad (37)$$

and the rotation will be unaccompanied by any change of scale if

$$\cos\theta = a_1 - kc_1 = b_2 - lc_2 = \frac{a_1 + b_2}{1 + c_3} \quad \dots \quad \dots \quad (38)$$

i.e. if $\qquad (a_2 - b_1)^2 + (a_1 + b_2)^2 = (1 + c_3)^2$

or $\qquad a_1^2 + a_2^2 + b_1^2 + b_2^2 + 2(a_1 b_2 - a_2 b_1 - c_3) = 1 + c_3^2$

which is readily seen to be true. To complete the conditions that X+P, Y+Q shall be deducible from x and y by a simple rotation and change of origin, we must choose α and β so that the common coefficient of X and Y in equations (33) and (34) is unity, *i.e.* we must have

$$c_3 + c_1\alpha + c_2\beta = 1 \quad \dots \quad \dots \quad \dots \quad (39)$$

which gives a straight line on which (α, β) may lie.

If we put $\frac{\alpha}{c_1} = \frac{\beta}{c_2} = \gamma$ then $\gamma = \frac{1}{1 + c_3}$ and we have

$$\left.\begin{aligned} X + P &= x\cos\theta + y\sin\theta + \frac{2a_3}{1 + c_3} \\ Y + Q &= -x\sin\theta + y\cos\theta + \frac{2b_3}{1 + c_3} \end{aligned}\right\} \quad \dots \quad (40)$$

20. These equations may be written in a variety of forms. In (40) the constant terms may be taken over to the left and subtracted from (X, Y), which is equivalent to moving the origin for (X, Y) to the point corresponding to the other plate-centre. If instead of this we move the origin of (x, y) to the plate-centre for (X Y) we may write the equations

$$\left.\begin{aligned} X + P &= \left(x - \frac{2c_1}{1 + c_3}\right)\cos\theta + \left(y - \frac{2c_2}{1 + c_3}\right)\sin\theta \\ Y + Q &= -\left(x - \frac{2c_1}{1 + c_3}\right)\sin\theta + \left(y - \frac{2c_2}{1 + c_3}\right)\cos\theta \end{aligned}\right\} \dots (41)$$

Or, finally, if we move *each origin halfway*, as has already been done in the case of the small terms P and Q, *i.e.* if we write

$$X_0 = X - \frac{a_3}{1 + c_3}, \; Y_0 = Y - \frac{b_3}{1 + c_3}, \; x_0 = x - \frac{c_1}{1 + c_3}, \; y_0 = y - \frac{c_2}{1 + c_3} \quad (42)$$

then we have

$$\left.\begin{aligned} X_0 + P &= x_0\cos\theta + y_0\sin\theta \\ Y_0 + Q &= -x_0\sin\theta + y_0\cos\theta \\ \text{where} \quad P = X_0(c_1 x_0 + c_2 y_0) &\qquad Q = Y_0(c_1 x_0 + c_2 y_0) \end{aligned}\right\} \quad \dots \quad (43)$$

This is theoretically the simplest form. Practically it is not so convenient, as it involves two additions or subtractions in place of one. We therefore use (40) or (41) in practice, in spite of the greater apparent simplicity of (43).

21. All this is quite rigorous and applies to any plates, however large. It may be noticed that $x_0 y_0$ $X_0 Y_0$ vanish together; and in the neighbourhood of this point, which is midway between the plate-centres, P and Q depend on the squares of small quantities at least, and are therefore small. If the plate-centres are as near together as those for the Astrographic Chart, P and Q never become large for the region common to the plates, and are readily applied by a small table or diagram. If, however, the plates are large, P and Q may be the most important parts of the formulæ and must be carefully calculated. We shall proceed no further with the consideration of such cases at present, but return to that where P and Q are small and readily applied, and especially to the case of plates of the Astrographic Chart.

22. In § 15 the determinant (27) gives the relations between two sets of standard coordinates in an approximate form, sufficiently accurate only when β and τ are small. But we can now form a more general expression. If $(A_1 D_1)$, $(A_2 D_2)$ be the plate-centres, and if $\alpha = A_2 - A_1$, then it can be easily found by procedure already indicated that the general determinant for transforming $(l_2 m_2 n_2)$ into $(l_1 m_1 n_1)$, or between $(\xi_2 \eta_2 1)$ and $(\xi_1 \eta_1 1)$ is

$$\begin{vmatrix} \cos\alpha, & \sin D_1 \sin\alpha, & -\cos D_1 \sin\alpha \\ -\sin D_2 \sin\alpha, & \cos D_1 \cos D_2 + \cos\alpha \sin D_1 \sin D_2, & \sin D_1 \cos D_2 - \cos\alpha \cos D_1 \sin D_2 \\ \cos D_2 \sin\alpha, & \cos D_1 \sin D_2 - \cos\alpha \cos D_2 \sin D_1, & \sin D_1 \sin D_2 + \cos\alpha \cos D_1 \cos D_2 \end{vmatrix} \qquad (44)$$

This is the relation *before* the quantities P and Q have been applied to one set; corresponding to the

$$\begin{vmatrix} a_1 & a_2 & a_3 \\ b_1 & b_2 & b_3 \\ c_1 & c_2 & c_3 \end{vmatrix}$$

of equation (30). *After* the application of P and Q we have shown that we may write the determinant

$$\begin{vmatrix} \cos\theta & \sin\theta & -C \\ -\sin\theta & \cos\theta & -F \\ 0 & 0 & 1 \end{vmatrix} \qquad \ldots \qquad \ldots \qquad (45)$$

where $\sin\theta = (a_2 - b_1)/(1 + c_3)$.

Thus $a_2 - b_1 = \sin a\,(\sin D_1 + \sin D_2)$

$$= 2 \sin a \sin \tfrac{1}{2}(D_1 + D_2) \cos \tfrac{1}{2}(D_2 - D_1) \qquad (46)$$

and $1 + c_3 = 1 + \cos(D_2 - D_1) - 2 \cos D_1 \cos D_2 \sin^2 \tfrac{1}{2}a$

or $\tfrac{1}{2}(1 + c_3) = [1 - \sin^2 \tfrac{1}{2}(D_2 - D_1) - \cos D_1 \cos D_2 \sin^2 \tfrac{1}{2}a] \qquad (47)$

Thus for Astrographic Chart plates, since even when a is large, $\cos D \sin a$ is always of the order β or τ (about one degree), $\tfrac{1}{2}(1 + c_3)$ differs from 1 by quantities of the second order. It can be quickly tabulated as far as the Pole.

23. The quantities C and F of (45) are given by

$$\left.\begin{aligned} \tfrac{1}{2}(1 + c_3)C &= \cos D_1 \sin a \\ \tfrac{1}{2}(1 + c_3)F &= \sin(D_2 - D_1) - 2 \sin D_2 \cos D_1 \sin^2 \tfrac{1}{2}a \end{aligned}\right\} \cdots \qquad (48)$$

and can also be quickly tabulated when a, D_2, and D_1 are given.

24. We have thus thrown the determinant for transforming one set of standard coordinates into another into a simple form (45), which lends itself to tabulation. The values of the quantities for the series of Astrographic Chart plates are tabulated at the end of this paper. This completes the theoretical part of the work. It remains to show by an example what numerical work is involved, and this we proceed to do.

Example of the Comparison of Plates.

25. Two plates were taken at the University Observatory, Oxford, with centres at (approximately)

$$A_1 = 1^h\ 56^m \qquad D_1 = +25° \qquad A_2 = 2^h\ 0^m \qquad D_2 = +26°$$

If $(x_1 y_1)$ denote measures on the first plate, referred to the *centre* of the *réseau* (if referred to the *corner* the transformation to centre is easily made), and $(\xi_1 \eta_1)$ the corresponding standard coordinates, it was found from comparison of the measures for stars with their standard coordinates computed from meridian observations (Cambridge and Berlin) that

$$\left.\begin{aligned} \xi_1 - x_1 &= -\cdot00767 x_1 - \cdot00841 y_1 + \cdot0833 \\ \eta_1 - y_1 &= +\cdot00852 x_1 - \cdot00755 y_1 + \cdot2285 \end{aligned}\right\} \quad \cdots \quad (49)$$

the coordinates and constant terms being expressed in *réseau* intervals. The determinant for expressing $(\xi_1 \eta_1 1)$ in terms of $(x_1 y_1 1)$ is thus (omitting the unities in the diagonal)

$$\begin{vmatrix} -\cdot00767 & -\cdot00841 & +\cdot0833 \\ +\cdot00852 & -\cdot00755 & +\cdot2285 \\ 0 & 0 & 0 \end{vmatrix} \quad \cdots \quad (50)$$

For expressing $(\xi_2\eta_2 1)$ in terms of $(\xi_1\eta_1 1)$, we refer to the tables at the end of this paper for $D_1=25°$, and find accordingly

$$\begin{vmatrix} -{\cdot}00003 & +{\cdot}00751 & -10{\cdot}8766 \\ -{\cdot}00751 & -{\cdot}00003 & -11{\cdot}9594 \\ 0 & 0 & 0 \end{vmatrix} \quad \ldots \quad (51)$$

It will be seen on reference to § 4 that (50) and (51) are identical with (4) and (5); and the combination has already been performed as an example of the process. The result is

$$\begin{vmatrix} -{\cdot}00764 & -{\cdot}00096 & -10{\cdot}7917 \\ +{\cdot}00107 & -{\cdot}00752 & -11{\cdot}7315 \\ 0 & 0 & 0 \end{vmatrix} \quad \ldots \quad (52)$$

which expresses $(\xi_2\eta_2 1)$ in terms of $(x_1y_1 1)$. We now want $(x_2y_2 1)$ in terms of $(\xi_2\eta_2 1)$. This is not given directly in the ordinary course. We ordinarily find $(\xi_2\eta_2 1)$ in terms of $(x_2y_2 1)$, as in the case of the first plate, viz. (referring to *centre* of *réseau*)

$$\left.\begin{aligned} \xi_2-x_2 &= -{\cdot}00754x_2-{\cdot}00200y_2+{\cdot}1217 \\ \eta_2-y_2 &= +{\cdot}00209x_2-{\cdot}00763y_2+{\cdot}2284 \end{aligned}\right\} \quad \ldots \quad (53)$$

and these are to be inverted. Now instead of inverting them as they stand, *take the constant terms over to the left* and write

$$X=\xi_2-{\cdot}1217 \qquad Y=\eta_2-{\cdot}2284$$

It is obvious that X and Y are very easily substituted for ξ_2 and η_2 in equations (52). We merely subtract ·1217 and ·2284 from the constants in the last column; and the equations

$$\left.\begin{aligned} X &= (1-{\cdot}00754)x_2-{\cdot}00200y_2 \\ Y &= \quad +{\cdot}00209x_2+(1-{\cdot}00763)y_2 \end{aligned}\right\} \quad \ldots \quad (54)$$

are readily inverted into

$$\left.\begin{aligned} \Delta\times x_2 &= (1-{\cdot}00763)X+\quad {\cdot}00200Y \\ \Delta\times y_2 &= \quad -{\cdot}00209\,X+(1-{\cdot}00754)Y \end{aligned}\right\} \quad \ldots \quad (55)$$

the coefficients on the right being written down by inspection of (54), and the value of Δ being

$$\begin{aligned} \Delta &= (1-{\cdot}00763)(1-{\cdot}00754)+{\cdot}00200\times{\cdot}00209 \\ &= 1-{\cdot}01511=(1{\cdot}01534)^{-1} \end{aligned}$$

Multiplying the coefficients of (55) by Δ^{-1} we get

$$\begin{vmatrix} +\cdot 00760 & +\cdot 00203 & 0 \\ -\cdot 00212 & +\cdot 00769 & 0 \\ 0 & 0 & 0 \end{vmatrix} \ldots \quad \ldots \quad (56)$$

which is to be combined with (52) modified, viz. :

$$\begin{vmatrix} -\cdot 00764 & -\cdot 00096 & -10\cdot 9134 \\ +\cdot 00107 & -\cdot 00752 & -11\cdot 9599 \\ 0 & 0 & 0 \end{vmatrix} \quad \ldots \quad (57)$$

Combining (56) and (57) we get finally

$$\begin{vmatrix} -\cdot 00010 & +\cdot 00104 & -11\cdot 0207 \\ -\cdot 00103 & +\cdot 00010 & -12\cdot 0288 \\ 0 & 0 & 0 \end{vmatrix} \quad \ldots \quad (58)$$

or in the usual notation

$$\left.\begin{aligned} x_2 - x_1 &= -\cdot 00010x_1 + \cdot 00104y_1 - 11\cdot 0207 \\ y_2 - y_1 &= -\cdot 00103x_1 + \cdot 00010y_1 - 12\cdot 0288 \end{aligned}\right\} \quad \ldots \quad (59)$$

in which we must remember that $(x_2 y_2)$ are supposed corrected by the small quantities P Q. From a *direct* comparison of the measured coordinates of 82 stars common to the plates we find (after similar correction by P Q)

$$\left.\begin{aligned} x_2 - x_1 &= -\cdot 00012x_1 + \cdot 00088y_1 - 11\cdot 0222 \\ y_2 - y_1 &= -\cdot 00090x_1 - \cdot 00011y_1 - 12\cdot 0275 \end{aligned}\right\} \quad \ldots \quad (60)$$

The differences between the two formulæ are

$$\left.\begin{aligned} &\text{in } x \quad +\cdot 00002x_1 + \cdot 00016y_1 - 0\cdot 0015 \\ &\text{in } y \quad -\cdot 00013x_1 + \cdot 00021y_1 - 0\cdot 0013 \end{aligned}\right\} \quad \ldots \quad (61)$$

which are applicable over a square region common to the plates from about

$$x_1 = -1 \text{ to } x = +12 \quad \text{and} \quad y_1 = -0\cdot 5 \text{ to } y = +12\cdot 5.$$

The extreme values of the differences at the corners of this region are

Coords.	$-1, -\frac{1}{2}$	$-1, 12\frac{1}{2}$	$12, -\frac{1}{2}$	$12, 12\frac{1}{2}$
Error in x	$-0''\cdot 48$	$+0''\cdot 15$	$-0''\cdot 40$	$+0''\cdot 21$
Error in y	$-0\cdot 38$	$+0\cdot 43$	$-0\cdot 88$	$-0\cdot 06$

These quantities are made up partly of accidental errors and partly of the systematic errors of the catalogues ; and it is for the detection and discussion of such systematic differences that this double method of comparison of plates is useful.

Tables for Astrographic Chart Plates.

The coefficients in the equations

$$\xi_2 + P = \xi_1 \cos\theta + \eta_1 \sin\theta - C$$
$$\eta_2 + Q = \eta_1 \cos\theta - \xi_1 \sin\theta - F$$

are given in the following tables :—

Table I. (*Plates one above another.*)

$A_2 - A_1 = 0$ $D_2 - D_1 = 2^\circ$

$\sin\theta = (1 - \cos\theta) = 0$ $C = 0$ $F = 24{\cdot}0025$ (*All zones.*)

Table II. (*Plates side by side.*)

$D_2 - D_1 = 0$ $A_2 - A_1$ ($= 2a$ say) variable with D_1.
From $D = 0^\circ$ to $D = 27^\circ$: $2a = 8^m$.

D	(1−cos θ)	sin θ	Réseau Intervals. C.	F.	Circular Measure. C.	F.
0°	·000000	·000000	24·0025	−0·0000	·0349102	−·0000000
1	000	·000609	23·9988	0·0073	·0349048	0106
2	001	·001218	23·9878	0·0146	·0348889	0213
3	002	·001827	23·9695	0·0219	·0348622	0318
4	003	·002435	23·9439	0·0291	·0348250	0424
5	005	·003042	23·9110	0·0363	·0347772	0529
6	·000007	·003649	23·8709	−0·0435	·0347188	−·0000633
7	009	·004254	23·8234	0·0506	·0346498	0737
8	012	·004858	23·7686	0·0577	·0345701	0840
9	015	·005461	23·7066	0·0646	·0344800	0941
10	018	·006062	23·6375	0·0716	·0343794	1042
11	·000022	·006661	23·5611	−0·0785	·0342683	−·0001141
12	026	·007258	23·4775	0·0852	·0341467	1239
13	032	·007853	23·3869	0·0918	·0340148	1335
14	036	·008445	23·2890	0·0983	·0338725	1430
15	041	·009035	23·1840	0·1047	·0337198	1523
16	·000046	·009622	23·0720	−0·1110	·0335569	−·0001614
17	052	·010206	22·9530	0·1171	·0333838	1703
18	058	·010788	22·8270	0·1231	·0332005	1790
19	065	·011365	22·6941	0·1289	·0330072	1875
20	071	·011940	22·5541	0·1346	·0328036	1958

D	(1 − cos θ)	sin θ	Réseau Intervals. C.	F.	Circular Measure. C.	F.
21°	·000078	·012510	22·4072	−0·1401	·0325900	−·0002038
22	084	·013077	22·2536	0·1455	·0323666	2116
23	092	·013640	22·0933	0·1506	·0321334	2191
24	101	·014198	21·9262	0·1556	·0318903	2263
25	108	·014753	21·7524	0·1604	·0316376	2333
26	·000117	·015303	21·5720	−0·1650	·0313752	−·0002400
27	125	·015848	21·3850	0·1694	·0311032	2464

From D = 28° to D = 36°: $2a = 9^m$.

D	(1 − cos θ)	sin θ	C.	F.	C.	F.
28	·000170	·018437	23·8406	−0·2197	·0346748	−·0003196
29	181	·019039	23·6157	0·2247	·0343476	3269
30	193	·019636	23·3834	0·2295	·0340098	3338
31	205	·020226	23·1441	0·2340	·0336617	3404
32	217	·020810	22·8977	0·2382	·0333034	3465
33	·000229	·021388	22·6444	−0·2422	·0329350	−·0003522
34	241	·021960	22·3842	0·2457	·0325565	3574
35	254	·022524	22·1172	0·2490	·0321681	3622
36	266	·023082	21·8433	0·2520	·0317698	3666

From D = 37° to D = 48°: $2a = 10^m$.

D	(1 − cos θ)	sin θ	C.	F.	C.	F.
37	·000345	·026259	23·9587	−0·3145	·0348466	−·0004575
38	361	·026863	23·6398	0·3176	·0343827	4619
39	377	·027459	23·3137	0·3201	·0339084	4656
40	393	·028046	22·9804	0·3223	·0334237	4688
41	410	·028625	22·6402	0·3241	·0329289	4714
42	·000426	·029195	22·2931	−0·3255	·0324240	−·0004734
43	443	·029756	21·9393	0·3264	·0319094	4748
44	459	·030308	21·5787	0·3271	·0313850	4757
45	476	·030851	21·2115	0·3273	·0308509	4760
46	492	·031384	20·8379	0·3271	·0303075	4757
47	·000509	·031908	20·4580	−0·3264	·0297550	−·0004748
48	526	·032422	20·0718	0·3255	·0291933	4734

From D = 49° to D = 59°: 2a = 12m.

D	(1 − cos θ)	sin θ	Réseau Intervals. C.	Réseau Intervals. F.	Circular Measure. C.	Circular Measure. F.
49°	·000781	·039510	23·6143	−0·4667	·0343456	−·0006788
50	804	·040103	23·1363	0·4641	·0336504	6750
51	827	·040684	22·6513	0·4609	·0329450	6704
52	851	·041252	22·1594	0·4572	·0322296	6650
53	874	·041808	21·6609	0·4530	·0315045	6589
54	·000897	·042352	21·1556	−0·4482	·0307696	−·0006519
55	919	·042882	20·6439	0·4428	·0300254	6441
56	942	·043398	20·1261	0·4368	·0292722	6354
57	963	·043902	19·6020	0·4304	·0285100	6261
58	985	·044392	19·0721	0·4235	·0277392	6160
59	·001007	·044869	18·5363	0·4160	·0269599	6051

From D = 60° to D = 63°: 2a = 16m.

60	·001829	·060429	23·9878	−0·7254	·0348888	−·0010551
61	1865	·061028	23·2586	0·7104	·0338283	10332
62	1900	·061608	22·5224	0·6945	·0327575	10101
63	1935	·062169	21·7793	0·6776	·0316767	09856

From D = 64° to D = 66°: 2a = 18m.

64	·002490	·070539	23·6547	−0·8354	·0344044	−·0012150
65	2526	·071128	22·8042	0·8120	·0331674	11810
66	2574	·071694	21·9468	0·7877	·0319204	11457

From D = 67° to D = 70°: 2a = 20m.

67	·003225	·080250	23·4209	−0·9413	·0340643	−·0013691
68	3272	·080832	22·4539	0·9090	·0326578	13221
69	3317	·081387	21·4801	0·8755	·0312416	12734
70	3361	·081918	20·4997	0·8411	·0298156	12233

From D = 71° to D = 74°: 2a = 24m.

71	·004898	·098862	23·4049	−1·1598	·0340410	−·0016868
72	4956	·099438	22·2144	1·1072	·0323095	16104
73	5012	·099984	21·0172	1·0533	·0305683	15320
74	5063	·100500	19·8137	0·9982	·0288179	14518

From D = 75° to D = 78°: 2a = 30m.

75	·007988	·126115	23·2339	−1·4709	·0337924	−·0021394
76	8056	·126681	21·7164	1·3811	·0315852	20087
77	8123	·127208	20·1922	1·2895	·0293684	18755
78	8187	·127697	18·6621	1·1964	·0271429	17401

From D = 79° to D = 82° : $2a = 40^m$.

D	(1 − cos θ)	sin θ	Réseau Intervals. C.	F.	Circular Measure. C.	F.
79°	·014647	·170505	22·7873	−1·9571	·0331428	−·0028464
80	14738	·171049	20·7369	1·7867	·0301606	25986
81	14824	·171542	18·6804	1·6142	·0271696	23477
82	14901	·171983	16·6186	1·4398	·0241707	20941

From D = 83° to D = 85° : $2a = 60^m$.

D	(1 − cos θ)	sin θ	C.	F.	C.	F.
83	·033575	·256955	21·6922	−2·8346	·0315501	−·0041227
84	33706	·257448	18·6043	2·4359	·0270589	35429
85	33823	·257867	15·5115	2·0344	·0225606	29589

From D = 86° to D = 87° : $2a = 90^m$.

D	(1 − cos θ)	sin θ	C.	F.	C.	F.
86	·075758	·381822	18·3573	−3·6426	·0266996	−·0052980
87	·075920	·382198	13·7717	2·7356	·0200301	·0039788

D = 88°, $2a = 120^m$.

D	(1 − cos θ)	sin θ	C.	F.	C.	F.
88	·13383	·499736	11·9986	−3·2131	·0174512	−·0046732

D = 89°, $2a = 180^m$.

D	(1 − cos θ)	sin θ	C.	F.	C.	F.
89	·29278	·707031	8·4852	−3·5141	·0123412	−·0051111

Table III. (*Corner Plates.*)

$D_2 - D_1 = 1°$: $A_2 - A_1$ variable with D_1

$D_1 = 0°$ to $36°$, $A_2 - A_1 = a = 4^m$.

D_1	(1 − cos θ)	sin θ	Réseau Intervals. C.	F.	Circular Measure. C.	F.
0°	·000000	·000152	12·0012	11·9993	·0174550	·0174523
1	0	0457	11·9994	11·9975	·0174524	4497
2	0	0761	11·9939	11·9958	·0174444	4471
3	1	1066	11·9847	11·9939	·0174311	4444
4	1	1369	11·9720	11·9921	·0174125	4418
5	·000001	·001672	11·9555	11·9902	·0173886	·0174391
6	2	1976	11·9355	11·9885	·0173594	4366
7	3	2278	11·9117	11·9867	·0173248	4340
8	3	2580	11·8844	11·9850	·0172852	4315
9	4	2881	11·8534	11·9832	·0172401	4289
10	·000005	·003181	11·8188	11·9815	·0171898	·0174264
11	6	3480	11·7807	11·9798	·0171343	4239
12	7	3778	11·7389	11·9781	·0170736	4215
13	8	4074	11·6936	11·9765	·0170076	4191
14	10	4370	11·6447	11·9749	·0169365	4168

D_1	$(1-\cos\theta)$	$\sin\theta$	Réseau Intervals. C	F.	Circular Measure. C.	F.
15°	·000011	·004664	11·5922	11·9733	·0168602	·0174144
16	12	4957	11·5363	11·9717	·0167788	4121
17	14	5248	11·4767	11·9702	·0166922	4099
18	15	5538	11·4137	11·9687	·0166006	4077
19	17	5826	11·3473	11·9673	·0165040	4057
20	·000019	·006112	11·2773	11·9658	·0164022	·0174036
21	20	6397	11·2040	11·9644	·0162955	4015
22	22	6679	11·1272	11·9632	·0161839	3997
23	24	6960	11·0471	11·9619	·0160673	3979
24	26	7238	10·9635	11·9607	·0159457	3961
25	·000028	·007514	10·8766	11·9594	·0158194	·0173943
26	30	7788	10·7865	11·9583	·0156883	3926
27	32	8059	10·6930	11·9573	·0155523	3911
28	35	8328	10·5962	11·9562	·0154116	3896
29	37	8594	10·4963	11·9552	·0152663	3882
30	·000039	·008858	10·3932	11·9542	·0151163	·0173867
31	41	9119	10·2868	11·9534	·0149616	3855
32	44	9378	10·1774	11·9526	·0148024	3844
33	46	9633	10·0648	11·9518	·0146387	3832
34	48	9886	9·9492	11·9511	·0144705	3822
35	·000051	·010135	9·8306	11·9504	·0142980	·0173812
36	54	·010382	9·7089	11·9500	·0141210	3805

$D_1 = 27°$ to $D_1 = 48°$: $A_2 - A_1 = 5^m$.

27	·000051	·010074	+13·3663	+11·9330	·0194405	·0173559
28	54	·010410	13·2454	11·9313	·0192646	3534
29	58	·010744	13·1204	11·9298	·0190829	3512
30	61	·011073	12·9915	11·9284	·0188953	3491
31	65	·011400	12·8586	11·9271	·0187020	3472
32	·000069	·011723	+12·7218	+11·9258	·0185031	·0173453
33	73	·012042	12·5811	11·9245	·0182984	3435
34	76	·012358	12·4365	11·9234	·0180882	3419
35	80	·012670	12·2882	11·9225	·0178725	3405
36	84	·012978	12·1361	11·9216	·0176513	3392

D_1	$(1-\cos\theta)$	$\sin\theta$	Réseau Intervals. O.	Réseau Intervals. F.	Circular Measure. O.	Circular Measure. F.
37°	·000088	·013282	+11·9804	+11·9207	·0174248	·0173380
38	92	·013582	11·8210	11·9201	·0171929	3370
39	96	·013877	11·6580	11·9194	·0169558	3361
40	100	·014169	11·4914	11·9189	·0167136	3353
41	104	·014456	11·3214	11·9185	·0164663	3347
42	·000109	·014739	+11·1479	+11·9181	·0162139	·0173342
43	113	·015018	10·9710	11·9179	·0159566	3339
44	117	·015292	10·7907	11·9178	·0156945	3337
45	121	·015561	10·6072	11·9178	·0154275	3337
46	125	·015826	10·4204	11·9179	·0151559	3338
47	·000129	·016085	+10·2305	+11·9181	·0148797	·0173341
48	134	·016340	10·0375	11·9184	·0145989	3346
			$D_1=48°$ to $D_1=59°$: $A_2-A_1=6^m$.			
48	·000192	·019608	+12·0448	+11·8823	·0175184	·0172821
49	198	·019907	11·8094	11·8828	·0171761	2828
50	204	·020201	11·5706	11·8835	·0168287	2839
51	210	·020488	11·3281	11·8843	·0164760	2850
52	216	·020770	11·0822	11·8853	·0161184	2864
53	·000221	·021045	+10·8330	+11·8864	·0157559	·0172880
54	227	·021313	10·5804	11·8876	·0153885	2898
55	233	·021575	10·3245	11·8890	·0150164	2918
56	238	·021831	10·0656	11·8906	·0146398	2942
57	244	·022079	9·8036	11·8923	·0142588	2966
58	·000249	·022321	+ 9·5386	+11·8941	·0138734	·0172992
59	254	·022557	9·2707	11·8959	·0134837	3019
			$D_1=59°$ to $D_1=63°$: $A_2-A_1=8^m$.			
59	·000452	·030074	12·3603	11·8145	·0179773	·0171834
60	461	·030378	11·9994	11·8180	·0174524	·0171886
61	470	·030674	11·6348	11·8219	·0169221	·0171942
62	479	·030960	11·2666	11·8259	·0163866	·0172001
63	488	·031236	10·8950	11·8302	·0158462	·0172063
			$D_1=63°$ to $D_1=66°$: $A_2-A_1=9^m$.			
63	·000617	·035139	12·2565	11·7850	·0178263	·0171406
64	628	·035439	11·8347	11·7906	·0172129	·0171488
65	638	·035728	11·4094	11·7965	·0165943	·0171573
66	648	·036007	10·9806	11·8026	·0159706	·0171662

$D_1 = 66^\circ$ to $D_1 = 70^\circ$: $A_2 - A_1 = 10^m$.

D_1	$(1-\cos\theta)$	$\sin\theta$	Réseau Intervals. C.	Réseau Intervals. F.	Circular Measure. C.	Circular Measure. F.
66°	·000800	·040006	12·2001	11·7561	·0177443	·0170986
67	812	·040303	11·7199	11·7641	·0170459	·0171101
68	824	·040588	11·2362	11·7722	·0163424	·0171219
69	835	·040861	10·7491	11·7806	·0156339	·0171342
70	845	·041121	10·2587	11·7894	·0149206	·0171469

$D_1 = 70^\circ$ to $D_1 = 74^\circ$: $A_2 - A_1 = 12^m$.

70	·001217	·049340	12·3090	11·6965	·0179027	·0170118
71	1232	·049637	11·7167	11·7093	·0170413	·0170300
72	1246	·049919	11·1210	11·7225	·0161749	·0170497
73	1259	·050185	10·5220	11·7361	·0153036	·0170695
74	1272	·050437	9·9194	11·7500	·0144272	·0170897

$D_1 = 74^\circ$ to $D_1 = 78^\circ$: $A_2 - A_1 = 15^m$.

74	·001988	·063031	12·3967	11·6093	·0 180303	·016885
75	2007	·063327	11·6402	11·6313	·0169300	·0169170
76	2024	·063602	10·8802	11·6539	·0158246	·0169499
77	2041	·063859	10·1169	11·6770	·0147144	·0169835
78	2056	·064095	9·3505	11·7004	·0135997	·0170175

$D_1 = 78$ to $D_1 = 82^\circ$: $A_2 - A_1 = 20^m$.

78	·003655	·085416	12·4607	11·4671	·0181233	·0166782
79	3680	·085705	11·4356	11·5093	·0166324	·0167396
80	3702	·085968	10·4070	11·5521	·0151364	·0168018
81	3723	·086205	9·3753	11·5955	·0136358	·0168649
82	3741	·086416	8·3407	11·6393	·0121310	·0169286

$D_1 = 82^\circ$ to $D_1 = 86^\circ$: $A_2 - A_1 = 30^m$.

82	·008410	·129424	12·4917	11·1886	·0181684	·0162731
83	8447	·129699	10·9384	11·2880	·0159092	·0164177
84	8477	·129935	9·3818	11·3882	·0136453	·0165635
85	8502	·130132	7·8224	11·4892	·0113773	·0167103
86	8524	·130290	6·2608	11·5907	·0091059	·0168580

The Cambridge Machine for Measuring Celestial Photographs.

By Arthur R. Hinks, M.A.

As a preliminary to the preparation, some three years ago, of plans for a new measuring machine for the Cambridge Observatory, the Director authorised me to prepare an account of the methods which had at that time been proposed and of the machines which had been made for measuring celestial photographs. Some notes from this account may serve as an introduction to the description of our new machine.

1. *Types of Modern Measuring Machines.*

Modern machines for measuring rectangular coordinates may be divided broadly into two types:

Type A, in which positions upon the photographic plate are referred to a standard scale on the measuring machine.

Type B, in which a *réseau* impressed upon the plate takes the place of the standard scale, and it is necessary only to measure the place of the star image within a *réseau* square.

There are two leading forms of machines of type A.

A 1, the Repsold machine described by Bakhuyzen (*Bull. Com. Perm.* I. 164), in which the microscope tilts on its chariot, and is pointed successively on the plate and on the standard scale.

A 2, various machines, like the Zeiss "Comparator," in which there are two microscopes rigidly connected together, one to view the plate, the other to view the standard scale.

It is required in both these forms that the main slides shall be geometrically perfect, or that their errors shall be investigated and applied; that the temperature corrections of the scale and plate shall be determined or in some way eliminated; and it is further required in form A 1 that the tilting motion of the microscope shall be perfect. These are all serious impediments. Moreover, it is almost universally admitted that to control the distortion of the gelatine film it is necessary to impress upon the plate a *réseau*. To refer the *réseau* lines as well as the star images to a standard scale, so that the distortions of the film are actually determined over the whole plate, is cumbrous. Historically this is the original use of the *réseau*. But it was quickly realised that its true use is to treat it as the standard scale. This proceeding straightway eliminates all necessity for considering film distortion except within the one *réseau* square in which the star image to be measured lies. Within this square the distortion must be considered uniform, showing itself as error of run (after correcting for errors of division of the *réseau*), and

eliminated in the usual way when the star image is referred to the four sides of the square which enclose it.

For the measurement of plate impressed with a *réseau* whose errors are known or which may be neglected, it is sufficient to use a machine of type B. Of such machines there were three years ago two principal forms :—

B 1, the machines used at Paris, Potsdam, and elsewhere, consisting of a microscope with field of view sufficiently large to take in a R-square (5 mm.) and a filar micrometer in the eyepiece to measure the distance of the star image from the sides of the square.

B 2, the machines used at Greenwich and Oxford, in which these distances were measured by estimation on a finely divided glass scale in the eyepiece.

Both these forms possess structural advantages over machines of type A. The principal slides which carry the plate under the microscope need not be very accurate. They can produce no errors in measurement unless they are so bad as to tilt the plate sensibly.

On the other hand, machines of type B 1 have one grave disadvantage, which is shared in some degree by all machines with micrometer screws. They involve a great deal of turning of the screws, which wastes time and wears out the screws. In the Potsdam machine, for example, the screw makes about 1,500 revolutions per hour. A complete measure requires in general about twenty turns, ten forward and ten back.

Machines of type B 2 have the advantage that an invariable glass scale is used instead of a screw ; but the last place in the readings is only an estimate of the proportion in which the scale interval is divided by the image of a R-line. The accuracy with which this estimate can be made is shown to be only just enough for the purposes of the Astrographic Catalogue, when something must be sacrificed to speed ; but it is not enough for work of any greater refinement.

2. *The Principle adopted for the Cambridge Machine.*

Since the *réseau* is always used at Cambridge the machine was to be of type B. I proposed to try a combination of the essential features of the two machines of this type described above, and to use a divided glass scale moved in the microscope by a micrometer screw. In this method the chief part of the distance to be measured is read off on the scale ; the fractional part of the scale space is not estimated, but measured by the screw, which carries the results to one more place of decimals. Since it is easier to place a star disc or a R-line symmetrically between two divisions than bisected by one, the spaces of the scale should be numbered instead of the divisions. The screw turns in a fixed nut, and its point bears against the frame

carrying the scale. The head of the screw should be divided so that readings of the head increase as it is turned to make the scale readings on the object diminish; the sum of the readings upon a fixed object of scale and screw, reduced to the same units, then remains constant.

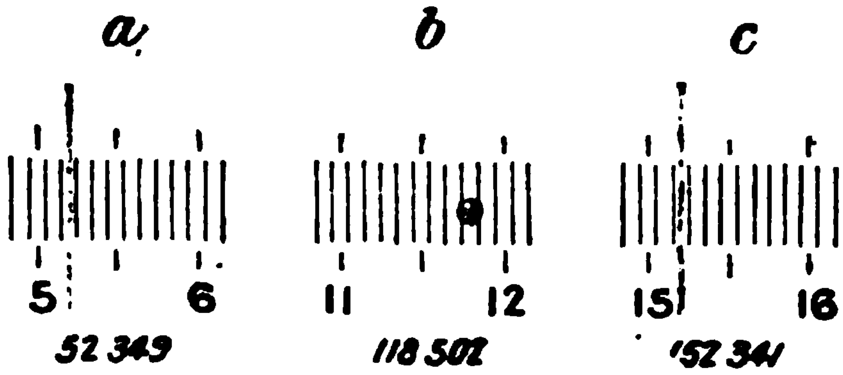


Fig. 1.

The method of making a measure on this plan is illustrated by the annexed diagram (fig. 1), which is drawn to represent the proportions which were adopted.

The R-interval is 5 mm.; 100 spaces of the scale = 1 R-interval; and the pitch of the micrometer screw is $0^{mm}\cdot 5$ = 10 scale spaces.

The R-square is brought into the field, and it is required to measure the distance of the star S from the line A.

The scale is moved by the screw until the nearest space is bisected by line A.

Scale reading 52, screw .349 say (fig. 1*a*).

The scale is then moved so that the star is placed symmetrically on an adjacent space.

Scale 118, screw .502 (fig. 1*b*)

And finally the line B is made to bisect a space.

Scale 152, screw .341 (fig. 1*c*)

The zero is of course perfectly arbitrary.

Now these numbers expressed as decimals of a R-interval are:

$$\left.\begin{array}{lll} A & 0\cdot 52 & 0\cdot 0349 \\ S & 1\cdot 18 & \cdot 0502 \\ B & 1\cdot 52 & \cdot 0341 \end{array}\right\} \quad \ldots \quad \ldots \quad \ldots \quad (1)$$

And adding corresponding readings of screw to scale we have:

$$\left.\begin{array}{ll} A & 0\cdot 5549 \\ S & 1\cdot 2302 \\ B & 1\cdot 5541 \end{array}\right\} \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (2)$$

It follows that the run is ·0008, correction positive, and the corrected distance of star from A is

$$·6753 + ·0005 = ·6758.$$

And it should be noted that the result is the same, whichever spaces are bisected, so long as the ratio of screw to scale is correct. We might have used different spaces and obtained the readings—

50	549
119	402
154	141

and these would reduce as before to the numbers of (2).

This arrangement seemed to possess the following advantages. The whole length of screw used in making the measure need never be more than one or two tenths of a revolution; there is therefore no time lost in running the screw backwards and forwards, and there is very little wear. It is scarcely possible that progressive error of the screw can come in; and since repeated settings should be made on different spaces, and consequently with different parts of the screw, periodic error would always tend to go out.

Finally, if it is desired to make rough preliminary measurements, the screws may be left untouched, and measures made by estimation on the scale, as in the Greenwich and Oxford machines.

3. *Details which are desirable.*

In order to be able to measure in both coordinates at once, it is desirable that the scale in the microscope should consist of two scales crossing at right angles and moved by two screws at right angles. Further, to obtain the full power of using the scale for estimation in the Oxford method, the eyepiece must command a field two R-intervals at least in diameter; and this is best accomplished by putting it on a slipping piece.

The microscope objective which projects an image of the plate on the micrometer scale is best placed to give a magnification unity. This arrangement possesses the convenient property that the image of the R-square can be made to fit the scale, and the error of run reduced to zero by racking the objective in or out with respect to its tube. No further adjustment is required. The plate remains in focus on the scale for a considerable range of motion of the objective, since for magnification unity the distance between conjugate foci of the lens is a minimum. This arrangement of the objective seems to be in common use, but its advantage has sometimes been lost because the objective has not been given a power of adjustment independent of the microscope tube.

A reversing prism in the microscope, by means of which the field of view can be rotated, is very useful in avoiding personality in measurement. In my own case it is a necessity, because the astigmatism of my eyes makes it impossible for me to see vertical lines as well as horizontal. The power of readily turning the field until the divisions of the scale I am using are horizontal is then a great convenience.

It is a well-known inconvenience of working with a micrometer that in making the settings the eye has to be close down to the micrometer heads, and must be withdrawn to read the heads. A minor inconvenience is that the nose has frequently to be pressed flat against the micrometer box. These difficulties can be avoided by using a compound microscope of low power instead of an eyepiece to view the micrometer scale. The divided heads are then further away from the eye, and in a position more convenient to handle. With the present machine it is easy to read the head with one eye without removing the other from the eyepiece.

It is an immense convenience if all adjustable parts are furnished with divided scales.

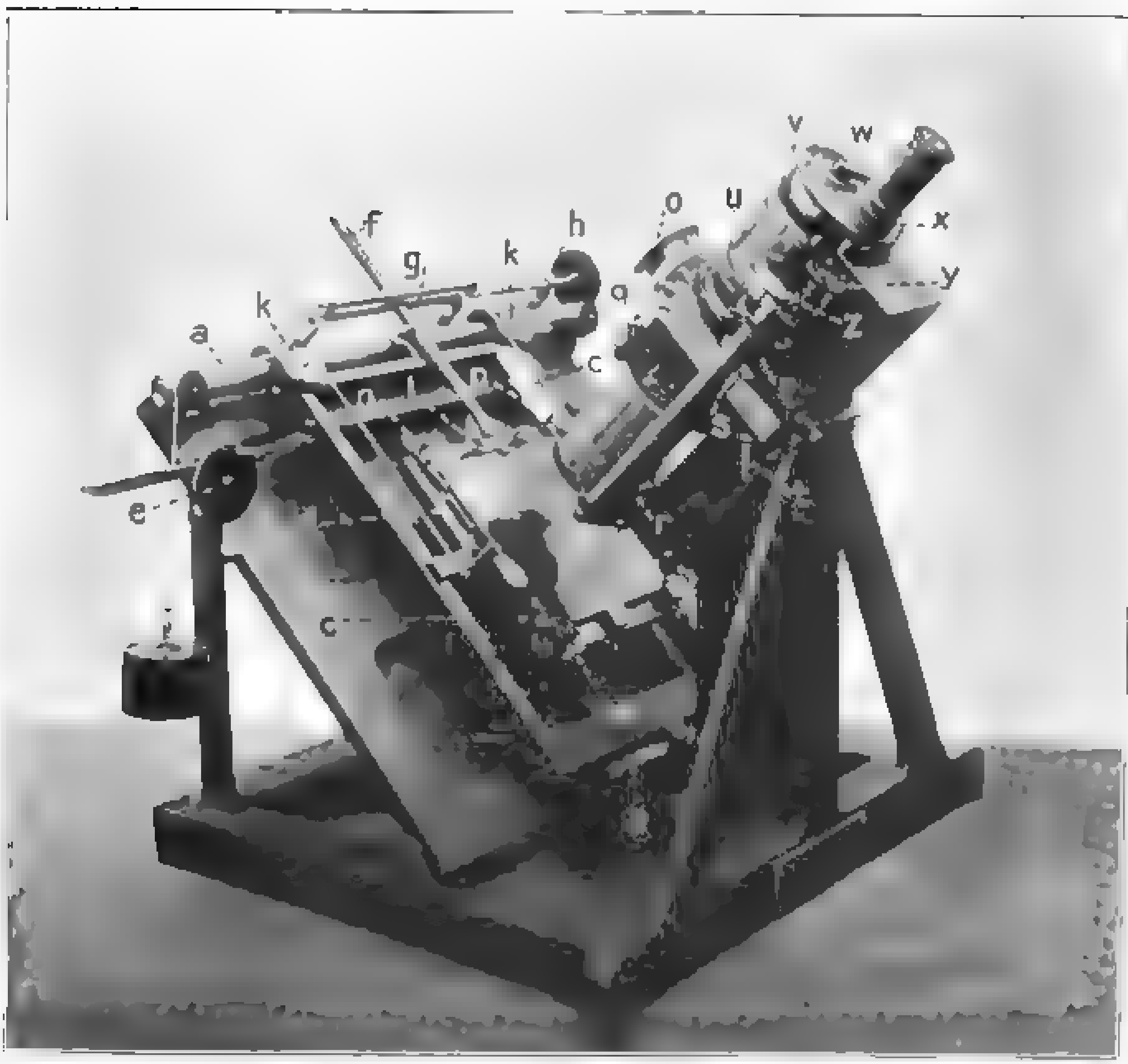
4. *The Construction of the Machine.*

The construction of the machine upon these lines was approved by the Director of the observatory, and the Cambridge Scientific Instrument Company, Limited, undertook the work. A draft of the features outlined above was sent, and plans embodying them were prepared by Mr. Horace Darwin. It is a pleasure to acknowledge the great debt which is due to him for the careful thought he has given to the design. Every detail of the machine was thoroughly discussed, and I think that all difficulties have been successfully overcome. Thanks are due to Mr. Newall for help in many ways; and several excellent ideas were borrowed from Sir David Gill's description of his new Repsold machine. Acknowledgment must also be made of the trouble which was taken by Messrs. Zeiss in arranging the optical parts, dividing the scale, and especially in designing for us a new form of reversing prism.

The accompanying photograph (Plate 12) shows the general appearance of the machine.

The base is a heavy iron casting resting on three feet, cast in one piece with the pillar which carries the microscope. Upon the base is erected a cast-iron frame which carries the main horizontal slides *a*, *a* of cylinder and plane form. On these rest a frame *b*, which carries the main vertical slides *c*, *c* of similar form, and on these slides rests the plate-carrier *d*.

The arrangements for giving motion to the plate-holder, and for counterpoising it on the vertical slide, demand a word of explanation. The frame *b* is moved along the horizontal slide by means of the rack and pinion *e*. The plate-holder carries a rack



THE CAMBRIDGE MACHINE FOR MEASURING CELESTIAL PHOTOGRAPHS

f which engages in a long pinion *g* parallel to the horizontal slide, and turned by the hand-wheel *h*. This gives a very nice motion in both coordinates at once. It is fairly quick, and at the same time delicate enough to do away with the necessity for a slow motion to the plate. There is a clamp on the vertical slide, which is useful when the plate is being run backwards and forwards on the horizontal slide to orientate it. But all the parts are so heavy that no clamp is required during measurement. To counterpoise the plate-holder on the vertical slide two cords are carried to pulleys *k*, *k*, at the top of the slide, and thence over pulleys at each side of the machine to two counterpoise weights. This is better than having one weight on a cord carried over the top. It reduces the weight to be carried on the horizontal slide, and does not interfere with the illumination from behind.

The plate rests upon three spring plungers, which brings its face up against three stops whose faces are worked to a plane parallel to the planes of the main slides, perpendicular to which the axis of the microscope is set. One of these stops, *l*, can be turned aside to permit the insertion of the plate. The lower edge of the plate rests at each end upon two pieces of long flat spring, which bear on the points of two adjusting screws *m* placed opposite the ends of the two extreme vertical lines of the *réseau*. Spring clips *n* on the top edge of the plate press it down against these springs, and the adjustment for orientation is easily made.

The microscope is in two parts, the body of each formed of turned steel tube, and resting in V bearings in a cradle fixed to the pillar. The four V's are accurately worked tangents to a cylinder. Fig. 2 shows the arrangement of optical parts and the position of the V's.

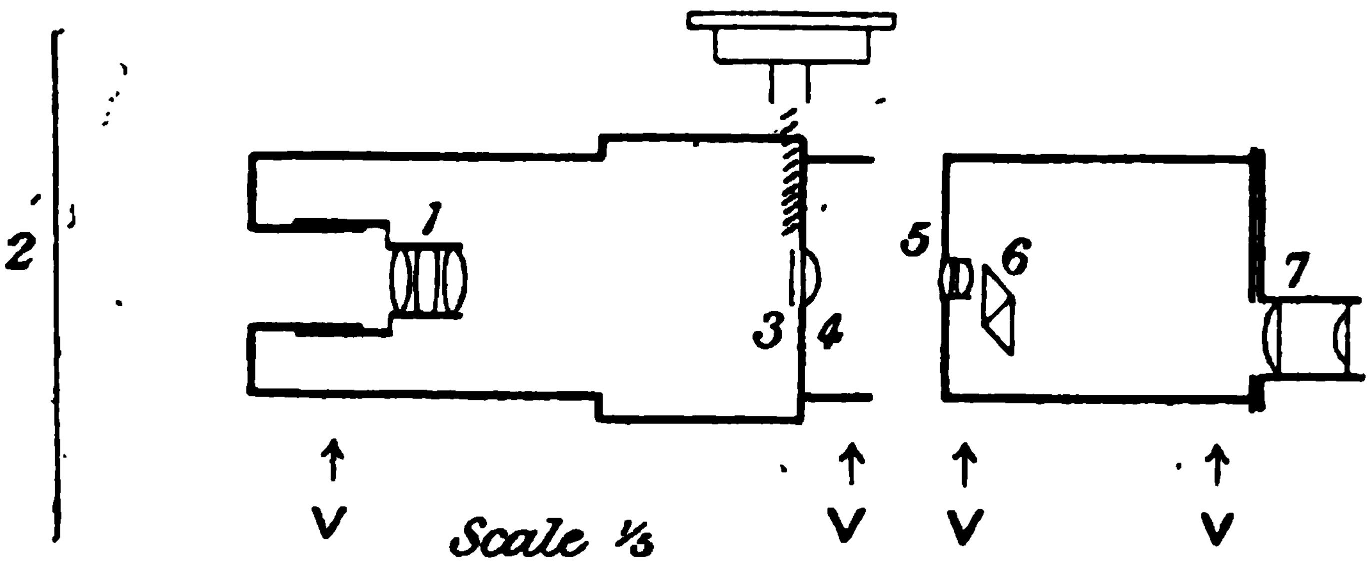


Fig. 2.

Objective I., at 1, is a Zeiss "symmetric anastigmat" combination of 60 mm. focal length. It projects an image of the plate 2 upon the divided glass scale at 3. The divisions, of course, are on the under side of the glass, so that the projection upon them is not distorted by the thickness of the glass. Immediately above the scale is a lens 4 termed by Messrs. Zeiss a

"collecting lens." Its function is to converge the axes of the pencils of light diverging from all points of the glass scale, without altering appreciably the angle of divergence of the beams in each individual pencil. This is necessary in order that the whole of the pencils should be brought into the objective of the view microscope.

Objective II., at 5, is a Zeiss "symmetric aplanat" combination of 35 mm. focal length. Immediately above it is the reversing prism 6, which is of a new form, devised by Messrs. Zeiss. The usual place for a reversing prism is outside the eyelens. When it is placed there it cuts down the field of view very considerably, as is well known, and this was inadmissible. The new reversing prism has three reflecting surfaces, and it is an irregular solid very hard to figure. But its action may be

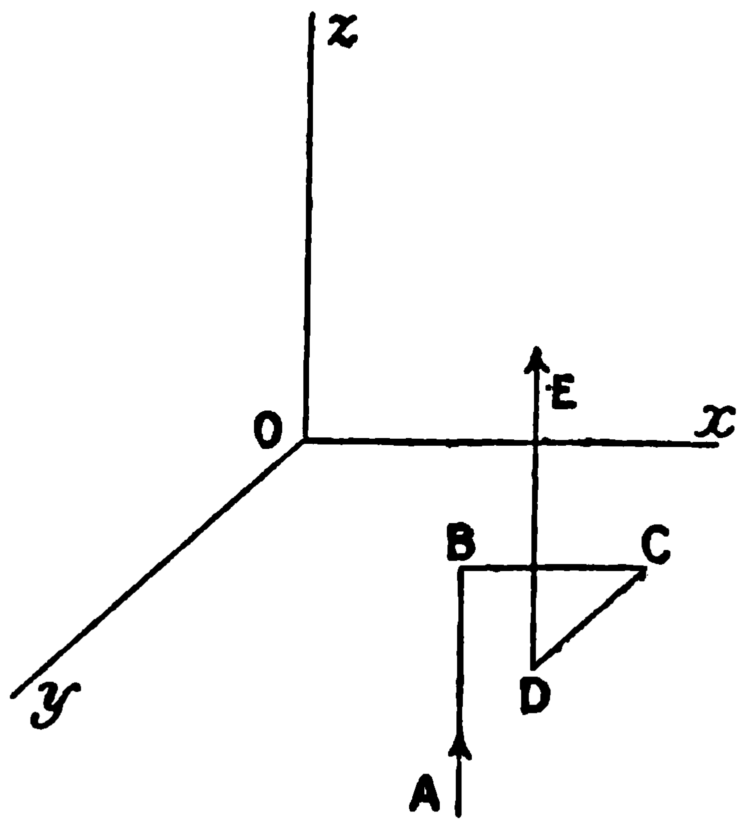


Fig. 3.

described thus: Let Ox, Oy, Oz be a system of rectangular axes. Let AB be the axis of the central pencil passing through objective II. It enters the prism at a face parallel to the plane xy. At B it is reflected parallel to the axis of x; at C parallel to the axis of y; and at D parallel to the axis of z; so that it emerges along DE parallel to its original direction AB, through a face parallel to the face of entry. If these faces are large enough to take the diverging beam from the objective there is no loss of field of view; and the definition of the microscope does not seem to be sensibly impaired by the action of the prism.

Since the optical axis is displaced parallel to itself, the eyepiece 7 must be mounted eccentrically on the end of the tube.

To return to the details of the mounting of these optical parts:

The objective 1 is mounted in a steel tube with four projecting studs, which bear outside a smaller steel tube fixed inside

the body of the microscope and turned concentric with it (see fig. 2). A spring keeps the two together, and a screw with divided head (seen reflected in the glass plate in the photograph) slides the objective tube along the other tube. This gives the motion of the objective required to fit the *réseau* square to the scale.

The double rectangular slide on which the divided scale is moved by the two micrometer screws is of a new pattern. It is geometrically desirable that the plane of the scale should coincide as nearly as possible with the plane of the slides, and this is difficult to manage if the slides are of the ordinary pattern, one crossing over the other.

The principle of the new slide is illustrated in fig. 4. The scale is held in a square block of steel, with two sides, AB, AC, ground accurately at right angles to one another, and to the face of the block. The points of the micrometer screws bear on these sides. Below the block is screwed a piece of steel forming two

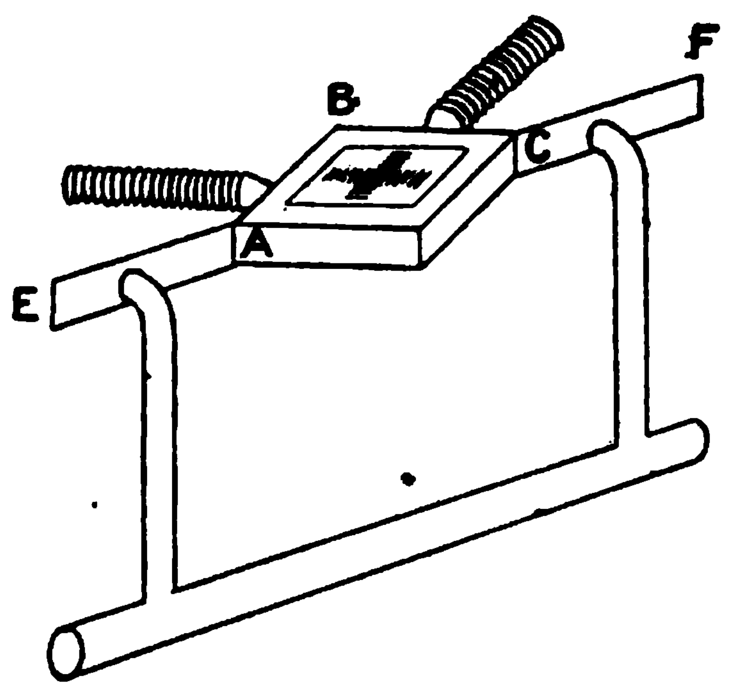


Fig. 4.

wings, AE, CF, with faces worked to a plane through the diagonal AC of the block, and perpendicular to its face. At some distance below is an axle working in V bearings parallel to AC; and from this axle spring two arms rigidly attached to it, which come up and bear against the faces of the wings. Spiral springs are wrapped round the axle, and the block is held against the points of the screws by the pressure of the arms upon the wings.

When either micrometer screw is turned the block is moved in a direction along the axis of the screw, and at the same time it is compelled to keep its diagonal AC always parallel to the axle from which the arms spring. The block has therefore motion in the plane ABC only in the two directions, mutually at right angles, of the axes of the micrometer screws.

Two long steel pins with sharp conical ends enter two shallow conical holes drilled in the under side of the block. The pins are driven upwards by spiral springs. This arrangement allows

ample lateral movement to the block, while it keeps its face ABC pressed against the worked inner surface of the top of the micrometer box, and it reduces friction of the slide to a minimum.

This new form of double micrometer slide is perhaps the most beautiful of the many pieces of ingenious geometrical design which Mr. Darwin has put into the machine. It is impossible to do justice to them in a brief sketch.

The micrometer screws *o* are of half-millimetre pitch. They were made by Messrs. Brown & Sharpe, of Philadelphia, U.S.A. The heads are of white celluloid divided into one hundred parts. Since the nut is fixed in the side of the micrometer box, and the motion transmitted by the point of the screw, the divided head has a considerable range of motion in the direction of its axis. The fiducial marks consist therefore of fine blackened silver wires stretched in frames and brought close down to the surfaces of the heads.

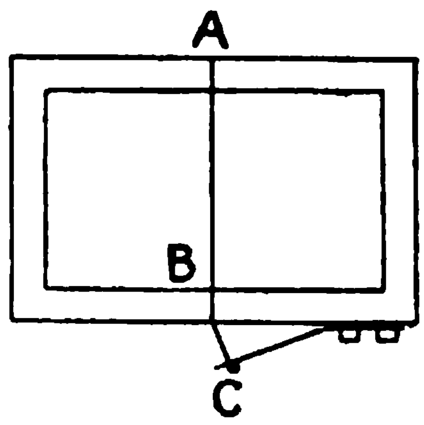


Fig. 5.

It is frequently required to mount fine wires in tension, and the ingenious method of fixing these wires used in this machine is worth describing. V-shaped cuts are made in the frame at A and B (fig. 5). C is a small piece of spring screwed to the side of the frame, and its end, which lies rather below the plane of AB, is pierced. A knot is tied in the wire; the wire is passed through the hole in C and laid in the cuts B and A; it is pulled up a little against the spring and fastened with a drop of solder at A. This arrangement keeps the wire always in tension.

The divided glass scale rests on three small projections in the edge of the square hole cut through the steel block. It is provided with an adjustment in orientation by which the scales may be set parallel to the axis of the micrometer screws. The complete glass scale will consist of two similar scales crossing at right angles. Up to the present Messrs. Zeiss have not been able to furnish an entirely satisfactory scale of this pattern, which seems to be difficult to make. The first crossed scale which they supplied consisted of two scales divided separately on thin glass and cemented face to face. This form was objectionable. It is essential that no thickness of glass shall be interposed between the scale and the objective, which projects on it the image of the plate. Otherwise there is introduced away from the centre of the field the distortion due to oblique passage through a parallel

plate, or perhaps to a plate not quite parallel. It did not seem worth while to incur the necessity of investigating and applying a troublesome small correction. The parts of the scale were therefore separated, and a single one is being used at present. Messrs. Zeiss hope to be able before long to supply the crossed scale ruled on one piece of glass.

The "collecting lens" in a steel cell is screwed into the top of the micrometer box *q*, so that it comes down very close to the scale.

This completes the description of the lower section of the microscope. The whole is free to turn in the lower pair of V's, *r*, *r* of the microscope cradle, through an angle of 90°. At the limits of its range of rotation it is brought up against stops *s*, adjusted so that the screws are parallel to the main slides, and spiral springs, *t*, can be hooked on to hold it in those two positions. It is possible therefore to measure the coordinates increasing with R.A. and Decl., or by turning through 90° with N.P.D. and R.A. The photograph shows the latter position. This power of rotation is of the greatest value in testing the centering of the somewhat complicated optical system.

The upper section of the microscope, with which the scale is viewed, consists of a low-power compound microscope, for the reasons outlined above. It is mounted in a steel tube *u* of the same diameter as the lower section of the microscope. Objective II. is screwed centrally into the lower end. Immediately above it is the reversing prism on a plate mounted on three screws by which the prism can be squared on to the optical axis. It should be remarked that this adjustment is not effective in the plane which contains the axis of the incident and emergent beams (the plane of fig. 2). A tilt of the prism in this plane produces no effect upon the direction of the emergent beam, which is controlled entirely by the angles at which the reflecting faces of the prism are worked.

The eyepiece plate *v* is double. A pin through the upper plate passes through an oval slot in the lower, and thence into a large flat washer. An arm *w* is attached to a nut on the upper end of this pin, and by giving it a slight turn the washer is tightened and the two plates clamped together. This makes a convenient slipping piece. If the eyepiece is held between the thumb and forefinger, the arm can be turned with the little finger and the nut loosened, the eyepiece slipped to the required position, and the whole clamped again.

There are three eyepieces which give powers, 20, 40, and 60 on the microscope. They are mounted on flanges *x* which have screws cut away like a gun breech, so that they slip home, and a slight turn holds them tight. Measuring is done with the power 20; but if any photographic defect in the image is suspected a higher power can be slipped in already adjusted to focus, and the suspected image examined.

The upper tube can be completely rotated in its V's. A turn through 45° turns the field of view through 90° by virtue of the

reversing prism. A weak spring catch holds the tube lightly in the eight positions in which the scale and *réseau* lines appear in the microscope horizontal and vertical.

There are three separate adjustments for focus. The milled head y slides the upper tube along its V's with respect to the lower, and brings the divided scale into focus in the eyepiece. The divided head z slides both tubes together along their V's, and brings the plate into focus on the scale. Finally, the divided head seen reflected in the plate gives an independent motion to objective I. and corrects any error of runs.

The two latter heads are divided on celluloid into one hundred parts: the first, because it is difficult to focus the plate on the scale with extreme accuracy at a single setting: a number of settings are made, and the head left at the mean reading; the second head was divided so that a given error of run could be corrected immediately without a series of trials.

This completes the description of the microscope.

The setting scales on the main slides (one of them seen through the plate in the photograph) are of white celluloid, divided to mm., and numbered in R-intervals. The numbers run both ways, one set in black, the other in red, so that a star can easily be found in either the direct or reversed position of the plate. The indexes are adjustable.

Some care has been taken to shield the measurer from all unnecessary light. The instrument stands on a table covered with black cloth. A black curtain hangs immediately behind the machine, with only a small hole in it to admit light to a reflector beneath the plate. Another black curtain hangs to the left. The greater part of the machine is painted dead black. These precautions make it possible to keep open the eye which is not in use; no light falls on it to dazzle it, and there is nothing bright in sight to attract its attention. The comfort and absence of strain on the eyes are very marked.

The essential parts of the machine are made of steel or cast iron, very massive. The machine is little sensitive to temperature, and its rigidity is remarkable.

5. *Rapidity and Accuracy of Measurement.*

It is as yet a little early to estimate definitely the rapidity with which measures can be made with this machine. The plates which have so far been measured with it have been measured in different ways for experimental purposes, and no long series of plates has as yet been treated in a systematic way. At present I have adopted the plan of making one pointing on each of two R-lines and two pointings on the star image for each coordinate. Working in this way, and recording one's own measures, it will, I think, be easily possible to measure twenty-five stars per hour in both coordinates.* This is of course much

* [Note added later.] Further practice has increased the rapidity to thirty stars per hour.

less than Sir David Gill's record, eighty stars per hour, including diameters, though it must not be overlooked that it takes two observers to do this, one recording for the other. When allowance is made for this the Cape machine is probably getting on for twice as fast, and it will be well to attempt to show that increased accuracy compensates in the Cambridge machine for diminished rapidity. On the other hand, the Cambridge machine is a great deal faster than those used at the Paris and other French observatories, where they measure from twelve to fifteen stars per hour.

It may be mentioned as a matter tending to rapidity that there is no need to record the measures in all the detail given in the example (Section 2). For instance, the scale and screw readings may be added together before the figures are set down; there is no need to take note for the second R-line of more than the last two figures of the micrometer reading; and even these need not be set down—they may be compared with the reading on the first, and the run set down directly. And since the mean run is easily reduced to nearly zero, the run of individual squares will rarely amount to ten units in the last place, and the necessary correction may be determined by inspection (see the example later in the discussion of the Cape machine).

The proportions of screws and scales were designed on the supposition that $0^{mm}\cdot0005$ is just less than the smallest amount of shift between two well-defined marks which can be appreciated by the eye with a microscope magnifying twenty diameters. This should make it just not possible to set continuously on a well-defined point to the same estimated figure on the micrometer head, but the range of variation should not be more than a few units in the estimated place. Some experience in determining division errors has shown that this estimate is certainly not too high. The probable error of a single setting on a perfectly defined mark is not so high as $\pm 0^{R}\cdot0001$ ($=0''\cdot017$ on the plate) when the observer is in good form. This is high testimony to the stability and workmanship of the machine; but it is of course no criterion as to the accuracy which may be expected in measures of star plates. Professor Kapteyn has given in *Publications of the Astronomical Laboratory of Groningen* (pt. i. p. 81) some interesting figures to show that the real accuracy in the measured position of a star image is much less than the accuracy estimated from the divergence of successive pointings on it, or even from the agreement of measures made in reversed positions of the plate; that is to say, the position of a star image has a real error of its own, independent of the errors of measurement, due to such causes as irregularities in the size and arrangement of the silver particles. The true P.E. of a measured position on the plate, deduced by comparison with the results of other plates, is therefore not a fair test of the capabilities of the machine; it depends more upon the defining power of the telescope, atmospheric disturbances, &c., as well as the quality of the plates.

The accuracy of the measuring machine is sufficient for its purpose if the errors in pointings due to the machine are much less than those due to irregularities in the star image.

Judged by this standard the Cambridge machine is amply accurate. A first determination of the P.E. of a complete measure (one setting on each R-line and two on the star in each position of the plate) derived from a direct reduction of one plate to another by means of eleven common stars, is $\pm 0^{R}\cdot 0004$, $= 0''\cdot 07$; whereas the P.E. of a *single setting* on a well-defined mark is less than $\pm 0^{R}\cdot 0001$. It is to be concluded that no gain in accuracy would result from making the micrometer screws finer.

6. *Errors of Screws and Scales.*

a. Progressive Error of Screw, and Ratio of Screw to Scale.—A well-defined speck was chosen on the plate, and every tenth division of one of the scales from 150 to 50 was set upon it in turn by the screw, the plate remaining fixed. The values of successive distances of ten-scale spaces in terms of the screw revolution were found to be $1^{r}\cdot 003$, 3, 2, 3, 2, 2, 2, 1, 2, 1; the small variations in these distances include of course division errors of scale as well as progressive errors of screw. There is evidently no appreciable progressive error in the screw over ten revolutions unless it should chance to be exactly compensated by a similar error in the scale; and this is shown later not to be the case. The pitch of the screw differs from that of the scale by about two-tenths per cent., which is negligible, since only fractions of a screw revolution are used.

b. Division Errors of the Scale.—These were partially examined by the method used by Sir David Gill in his investigation of the heliometer scales (*Monthly Notices*, xlix. p. 110). An etched scale by Zeiss was mounted on a plate and used as the auxiliary scale. The space between 150 and 50 was taken as correct, and the error of every tenth intermediate space found. The means of two determinations, which agreed well, gave for the corrections -12, $+4$, $+9$, $+3$, $+3$, $+17$, $+13$, $+32$, $+8$, all multiplied by 10^{-5} R-intervals. Only one of these is at all large, and that is due to an obviously bad cut of one division, which would be avoided in use.

A similar examination of the error of every alternate space from 110 to 90, assuming the errors for these spaces found above, gave for the intermediate space errors $+9$, $+12$, $+14$, $+3$, -3, -4, -8, $+13$, $+6\times 10^{-5}$ R-intervals.

It is evident that the division errors of the scale examined rarely amount to more than one in the last place of decimals used ($\cdot 0001$ R$=\cdot 0005$mm.). It seems safe to treat these errors as accidental.

c. Periodic Errors of Screws.—An examination was made of the screw used with the single scale at present in use. No periodic term could be detected having a coefficient so large as a

single thousandth of a screw revolution. If there are periodic errors they are so small that they could not be determined without using a reading microscope to read the divisions of the head to a greater accuracy than estimation of tenths gives. The screw may therefore be pronounced perfect.

7. *Comparison between the Cambridge Machine and Sir David Gill's Repsold Machine.*

It is not fair to compare directly the performances of the Cape and Cambridge machines, because the former was designed for the measurement of the astrographic catalogue plates, and something is admittedly sacrificed to speed. On the other hand the Cambridge machine was made for measuring plates for parallax determinations, and the highest attainable accuracy is the first consideration. It is, however, admissible to suggest that it seems probable that the principle of the Cambridge machine could be adapted to the Cape work, with a gain in accuracy, and no loss of speed.

Professor Turner has brought forward several objections to the Cape machine (*Monthly Notices*, lix. p. 135, 1899 Jan.). The weightiest is the conclusion that on Sir David Gill's own showing (*Monthly Notices*, lix. p. 73, 1898 Dec.) the micrometer screws of his machine should be already worn out. It seems to me that this estimate is exaggerated. It is based upon a comparison between the microscopes of the meridian circle and the measuring machine. In the former, if a complete determination of run is made for each reading, the screw must be turned through a range of 5 rev. backwards and forwards each time. In the latter the screw is turned only from star to star within the R-square, and is not set upon the R-lines themselves. The criticism appears, however, to apply precisely to the use of the screws in the Paris and Potsdam machines. In any of the cases the wear of the screw soon spoils the accuracy of the machine.

A second objection which Professor Turner brought forward is the partial neglect of error of run. Sir David Gill gives reasons for believing that its effect is small. Reference to his paper, p. 67, shows that he adjusts his square of webs to fit the mean R-square on the plate, and that if any individual R-square does not fit the webs he makes a symmetrical pointing on it; the position of the star image should thus be referred to the middle of the square, and the effect of run halved. The efficacy of this procedure seems to me somewhat doubtful. In placing the R-square on the square of webs attention must be concentrated on one line or the other, and the accuracy of setting on the one is considerably greater than the power of perceiving afterwards a want of symmetry in the other—at least, it seems so to me. It is probable that on this account, when the runs are small, the setting is made on one line, and the symmetry of the other is regarded as sufficient when it is really not so. The

error of run would then come in to its full amount. This remark does not of course apply to large errors of run, which are readily enough perceived, but to the continual small changes, due to distortion of film, errors of R-lines, and want of flatness of plate, which are evident to measurement, but scarcely apparent to inspection.

I venture, with some diffidence, to suggest that the principle of the combined scale and screw might be used in the Cape type of machine with very little, if any, loss of speed and some gain in accuracy. At the Cape Observatory the measurers work in pairs, one acting as clerk to the other. Suppose the measures made exactly as I have described in paragraph 2, and let us take the figures used in that example. The observer makes the setting on the first R-line and calls out 52,349; the recorder enters this at once as 5549. The observer now sets on the other R-line with results 152,341; the recorder need only do the simple subtraction of the last figures in his head, $49-41=+8$, and record "run +8." Finally the observer sets on the star with readings 118,502. The recorder enters these as 12302, and while the observer is finding the next star performs the subtraction $12302-5549=6753$, adds 5 for run, and writes down the corrected result ·6758. The observer has to make one more setting per star, three instead of two; but on the other hand he saves the time spent in giving several turns to the screw. The recorder has more work to do, but I think he could keep pace with the observer after a little practice. The result should be more accurate, since runs would be rigidly allowed for; the screw would not wear out nearly so quickly, and there would be no anxiety about permanence of somewhat complicated adjustments.

The rapidity of measurement which might, I think, be attained with the Cambridge machine used in this way depends of course on the condition that two people are available for the work. It is rather a special case which was not contemplated in the work for which the machine was designed. But the very satisfactory results which the combination of screw and scale has given at Cambridge seem to be some excuse for entering rather at length into the question whether their use might not be the means of avoiding one or two of the objections which have been raised to the methods adopted at the Cape Observatory, and more recently at Sydney and Melbourne, for the measurement of the Astrographic Catalogue plates.

I am indebted to the Cambridge Scientific Instrument Co. for the negative from which the plate illustrating this paper was prepared.

Cambridge Observatory: 1901 *May* 3.

Note on the Geometry of the Siderostat. By H. C. Plummer, M.A.

1. In the following note I have collected some of the principal geometrical propositions which relate to the siderostat and the motions connected with that instrument. There is little that can be considered essentially new in this account, but at the same time it may not be altogether useless to attempt to put the theory in a simple and clear light. Hitherto the siderostat has engaged the attention of the physicist rather than of the astronomer, and it is in France especially that its development has been promoted, while in this country it has been comparatively neglected. For these reasons there is perhaps some excuse for considering the matter in this place.

2. The principal propositions to which reference is made, and which are nearly all quite well known, are these:

1. The normal to the mirror describes a cone of the second order.
2. The circular sections of this cone are (*a*) perpendicular to the axis of the Earth, and (*b*) perpendicular to the ray reflected in a fixed direction.
3. The section (*a*) is described with uniform motion.
4. The section (*b*) is described with motion derived by stereographic projection from uniform motion.
5. The intersection of the mirror with the plane of reflexion describes a cone of the second order.
6. The circular sections of this cone are (*c*) perpendicular to the axis of the Earth, and (*d*) perpendicular to the ray reflected in a fixed direction.
7. The section (*c*) is described with uniform motion.
8. The rotation of the field is precisely the same as the motion with which the section (*b*) is described.

3. In the figure (fig. 1) which illustrates this note all directions are referred to a sphere of which the centre is C, the fixed centre of the siderostat mirror. The instrument is so adjusted that the star S, whose N.P.D. is δ, is reflected in the fixed direction CA. Hence the normal to the mirror CN bisects the arc SA. The pole is P, and is reflected to Q, so that the arc PQ is also bisected at N. It is at once obvious that AQ is equal to PS, and that Q therefore describes a circle round A of angular radius δ. The lines ACA′, PCP′ are diameters of the sphere. The intersection of the mirror with the plane of reflexion is represented by CM. This line is perpendicular to CN, and lies in the plane ASA′, which is clearly the plane of reflexion.

4. All the geometrical properties enumerated above become evident when the figure is examined. The lines A′S and CN are parallel for $SA'A = \frac{1}{2} SCA = NCA$. Similarly P′Q and CN are parallel for $QP'P = \frac{1}{2} QCP = NCP$. Hence the three

lines A′S, P′Q, and CN, being parallel, generate cones which are similar and similarly placed. It follows that parallel sections of all three cones are similar. But the cone whose vertex is at A′ has a circular section which is uniformly described in a plane perpendicular to CP, and the cone whose vertex is at P′ has a circular section in a plane perpendicular to CA. Hence sections of the cones which are parallel to either of these planes are circular. Now the section perpendicular to A′A of the cone

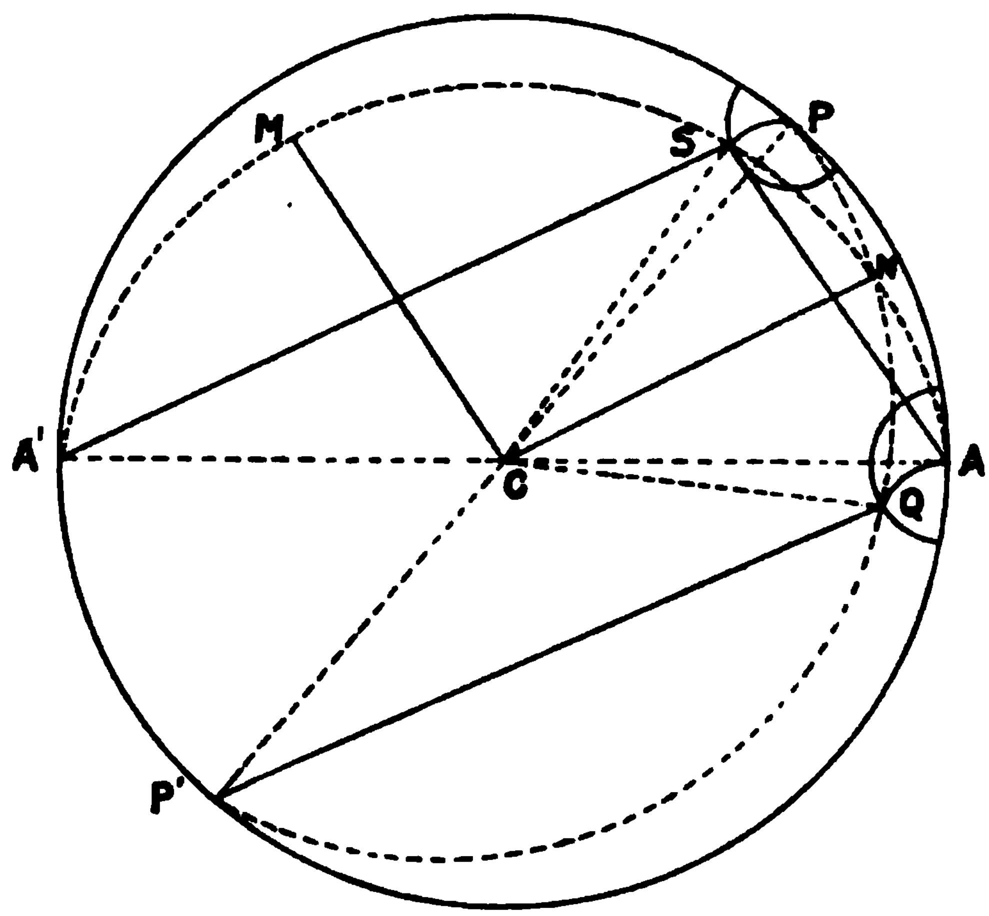


Fig. 1.

whose vertex is at A′ is the stereographic projection of the locus of S, which is the other circular section. We have thus obtained incidentally a fairly simple proof of the well-known theorem that the stereographic projection of a circle is a circle. But we have at the same time proved the propositions in § 2 numbered 4 and 8 as well as those numbered 1–3. The last proposition on the list is, as far as I know, new, and was obtained analytically before the possibility of so simple a geometrical proof was realised.

5. The remaining theorems refer to the motion of CM, and are derived with equal facility. For since CN is parallel to A′S, and CM is perpendicular to CN, CM is parallel to AS. Hence CM and AS generate cones which are similar and similarly placed, and the circular sections of the one are made by the same planes as those of the other. But the cone whose vertex is at A has for its sections the locus of S and the stereographic projection from A of this locus. The theorems 5–7 of § 2 follow at once.

6. The connection between the rotation of the field and the motion of the normal to the siderostat mirror suggests the possibility of deriving the mechanism for giving compensating motion to a photographic plate from the siderostat itself. The convenience

and advantage of such an arrangement are obvious, but there are also difficulties to be anticipated. If it proved that these could be overcome, an interesting solution of the problem of compensation would result. It may be pointed out that in the stereographic projection from A′ of the small circle which is the path of S, the projection of P is not of course the centre, but corresponds to the point B (fig. 1, p. 402), which represents the position of the fixed pin employed in the method I have suggested recently for compensating the rotation. Hence we have this theorem in stereographic projection: The plane A′SP cuts the circle S again in S′. The projections of S and S′ are S_1 and S_1'. If the circle S is described uniformly, S_1' describes the projected circle uniformly, while the motion of S_1 obeys the law

$$\tan \tfrac{1}{2}\theta = \mathrm{K} \tan \tfrac{1}{2} nt$$

7. The quite simple description of the geometry of the siderostat given above will render clear the principles which underlie the construction of this instrument. In Silbermann's device CS and CA are produced backwards and materialised as bars, and a linkage is added to form a rhombus with the diagonal of which coincides a slotted bar which is normal to the mirror. In all other devices the properties given in § 2, 3, or 7 are employed, and accordingly two types have resulted. In the one class we have the mirror driven by a rod fixed normal to the mirror; in the other by a rod or bar fixed in the plane of the mirror. The former type seems to have been first realised by S'Gravesande, and may be considered by imagining the mirror at A′ instead of C. Then A′S will represent the direction of the normal, which in its material form must of course be reversed, as A′T (fig. 2). It is only necessary to make T describe a

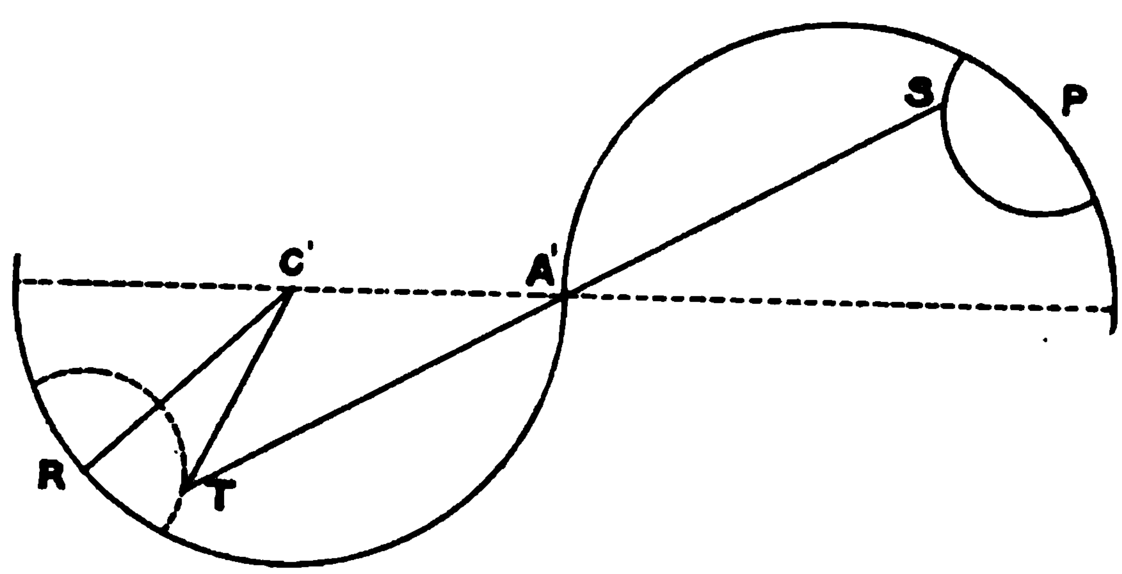


Fig. 2.

small circle about the polar axis RC′ on a sphere which passes through the centre of the mirror. The point T represents a ring through which the normal passes, and which can be set at the appropriate polar distance. The second type of instrument was devised by Gambey. If we imagine the mirror transferred to A,

it is easy to see, as in the other case, how the necessary motion is given to AS, the line in the plane of the mirror. But further the plane of the mirror must remain perpendicular to the plane ASA′. To secure this, that central line of the mirror which is perpendicular to the driving rod is constrained to remain perpendicular to CA, the direction of the fixed reflected ray. Thus the plane of the mirror contains a line which is perpendicular to two lines in the plane of reflexion, and the required condition is fulfilled. A small instrument, which has been found very useful, has been designed by Dr. Johnstone Stoney on this principle. The siderostat of Foucault combines some of the features of both types, the motion of the mirror being controlled partly by the normal rod and partly by a slotted bar in the plane of the mirror and passing over a rod which is the prolongation of TC′ (fig. 2). The bar is thus kept parallel to AS (fig. 1), as is easily seen, and provides the means of maintaining automatically the longer dimension of the mirror (if this is neither circular nor square) in the plane of reflexion.

The description of these instruments is of course too brief to convey a very satisfactory idea of the details of their construction. What is aimed at is to point out the relations of the different types. The principles outlined here will probably suffice to render the mechanism of any particular instrument immediately intelligible on inspection of the concrete example.

Oxford: 1901 May 9.

The Spectrum of Nova Persei. Note 4.

By the Rev. Walter Sidgreaves, S.J.

In note 3 on the spectrum of *Nova Persei* in the last number of *Monthly Notices* it was observed that at the times of minimum of the light curve the bright Hζ band was greatly extended on its violet side, and that one of the blue bands appeared to be too bright to be satisfactorily explained by the greater contrast of a weaker continuous spectrum.

The photograph of March 28 shows two prominent lines of greater brightness in the so-called extension: one at its red side adjoining, or perhaps overlapping, the hydrogen band ζ, and the other near its margin on the more refrangible side. The wavelengths of these two lines are found to be 3882 and 3859, referred to the centre of bright Hβ. The extension may therefore be a cyanogen band, composed of the nineteen lines measured by Lockyer * between 3883 and 3855, of which the strongest lines are 3883, 3871, 3862, and 3855; and it will be convenient to call it, provisionally, the CN band. This band and the most prominent of the blue bands at 4633 are the characteristic features of the spectrum at the minima of the light curve. Both bands either

* Watts, Index of Spectra 168, revised edition.

come into being at these times, or are completely absorbed at times of greater general brightness of the star, neither of them being accounted for by the greater contrast of a feebler continuous spectrum; for at Hζ the continuous spectrum was never so bright as the CN band, and the blue band is not a previously existing band grown stronger, but it occupies the space between two previous bright bands, in the same manner as the CN band occupies the space between Hζ and Hη.

The dates on which this spectrum has appeared are indicated by the brackets in the following list, and may be called the minimum type: February 28, March 3, 7, 8, 12, 16, 17, 20, 21 (22), (25), 27 (28), April 1, 4, 5, 9 ? (11), (12), (13), (16), 19 (20), (21), 23 (25), (26). On the other dates not in brackets the CN band is completely absent, and the blue band 4633 is replaced by a pair of bands, one on each side of its position. And it is noteworthy that the pair of bands appeared for the first time on March 21, the day before the first photograph of the minimum type spectrum. They had formed from a very broad bright band covering about 5 $\mu\mu$, which had been a constant feature of the spectrum from February 28 to March 20.

The query written against April 9 in the above list of dates signifies uncertainty of the type of spectrum on that date. It seems to be in the state of transition from the non-minimum type to that of the minimum, or *vice versa*; the CN band is absent, but the blue band 4633 is present in a diffusive state, and not strong, and without its otherwise constant companion at 4681.

The radiant energy of the CN band seems to be very great. On the later dates, notwithstanding the low altitude of the star and the sensibility curve of the plate, it is stronger than Hδ. At the same time a remarkable change appears in the relative strengths of Hϵ and Hδ. On the spectrographs of April 16, 20, 25, and 26, Hϵ is stronger than Hδ, and the CN band is stronger than Hϵ; so that the relative intensities of these three bands are in the inverse order of the sensibility curve, and the relation is not exaggerated by expressing the density of the silver deposit at Hδ by d, and writing $2d$ and $3d$ for the densities at Hϵ and the CN band.

Stonyhurst College Observatory:
1901 *May* 5.

The Visual Spectrum of Nova Persei.
By the Rev. A. L. Cortie, S.J.

The following observations of the visual spectrum of *Nova Persei* were taken by means of an equatorially mounted refracting telescope with an excellent 5-inch object-glass by Alvan Clarke, but without clockwork, and a McClean eyepiece star spectroscope of small dispersion. The estimates of the magnitude of the star during the times of the observations, after the star

became invisible to the naked eye, were made in the small finder of the instrument by Mr. Joseph Ronchetti. The observation of the star's spectrum on April 21 is also due to the same observer, and he assisted in all the other observations. The wave-lengths of the lines, which are given to three figures, do not pretend to any degree of exactness, but may be a guide to the identification of those lines the origin of which was not at once evident. They were derived by a comparison of eye estimates with the photographs of Father Sidgreaves, and that taken on February 28 by Professor Hale, and published in the Yerkes Observatory Bulletin No. 16. By this means it was quite easy to fix the approximate mean wave-lengths of the bright and dark bands observed in the small instrument employed. The details of the observations are as follows.

On the three nights, March 12, 16, 20, the predominant lines were the hydrogen lines α, β, and γ, the first two being very brilliant, a bright yellow line, presumably D, and a bright triplet in the green comprising the *b* group, and bands at λ 500 and λ 550. On the 12th a broad dark absorption band, slightly more refrangible than D, was seen, identified by Professor Hale (*loc. cit.*) as corresponding to D_3.

On these three nights the magnitude of the star during the times of observation between the hours of 9 and 11 P.M. was estimated as equal to δ, between ν and κ, and equal to ν—or 3, nearly 4, and 4. The colour on the 12th and 16th was noted as very like that of the planet *Mars*.

On the 21st the magnitude of the star was estimated as slightly less than ν, or fourth magnitude. The night was perfect for seeing, and no less than sixteen bright and dark bands and lines were observed. Of these, nine were bright lines, $H\alpha$, $H\beta$, D, *b*, λ 500, λ 466, a band still more refrangible, and two others in the red, the one less and the other more refrangible than $H\alpha$. The former of these is very probably the line λ 6678 due to helium, and so frequently observed in company with D_3 in solar prominences. It was again seen on March 28, when the star had fallen to the sixth magnitude. The same line is represented in the drawing of the visual spectrum of *Nova Aurigæ* made by Professor Campbell at the Lick Observatory on 1892 February 28.

The other very faint and fine bright line likewise seen in the red was estimated at one-third of the distance between C and D, somewhere about λ 640. This line was again seen on the 25th, was invisible on the 27th, and reappeared on the 28th, thus becoming visible when the star fell in magnitude to 6, and disappearing with the intermediate rise of the star to the fourth magnitude.

Of the other bright lines the *b* group and λ 500 were as broad but not so brilliant as $H\beta$; $H\alpha$ and D were bright, while λ 466 first forced itself upon notice on this night. It has since remained a prominent member of the bright line series.

The seven dark spaces comprised more refrangible companions to Hα and Hβ, dark D_3, and dark spaces in the green less refrangible than b, λ 500, and Hβ. The remaining dark space intervened between λ 466 and Hγ. Their mean wave-lengths would be approximately λ 540, λ 510, λ 498, and λ 445. Of these, λ 510 and λ 498 were the most marked. There was also continuous spectrum in the region from D to λ 540, in which, however, no details could be made out with certainty.

On March 25 the star was just visible to the naked eye, being estimated as equal to l, or 32 of Cottam's charts, which is of magnitude 6. The bright lines seen were Hα, the line in the red about λ 640, D, b, λ 500, Hβ, λ 466; a wonderful spectrum for visually so small a star. The dark spaces were λ 540, λ 510, λ 498, which was between two and three times as broad as Hβ, and the dark space more refrangible than Hβ about λ 480, which, too, was very broad. The spectrum in its main details was not unlike that of March 21, except that it was less brilliant. Hα, however, and the bright space at λ 466 were quite as bright as on the former date.

On March 27 the star's magnitude had risen again to nearly 4, when first observed at 9.30, though at 10 P.M. it had sunk about half a magnitude. The bright lines seen were Hα, now the brightest of all; D, not so bright as on the 25th; b, only glimpsed; λ 500, well seen; Hβ, not very brilliant and seemingly diminished; λ 466, brighter and well seen; and Hγ. The dark companion to Hα was just visible, as was also dark D_3, and λ 498 and the companion to Hβ were seen.

On March 28 the star had again fallen to magnitude 6, and became even fainter during the course of the observations. The spectrum resembled that of the 25th, the luminosity having shifted to the red and orange. There was a very great increase in the brilliancy of the D line, and Hα was, too, very bright, equalling Hβ in intensity. The two faint lines, one on each side of Hα, first seen on March 21, were again visible. The b group was very faint and occasionally visible, but λ 500 almost equalled Hβ in brightness. Hβ, however, was less brilliant than on the 21st. The band λ 466 had increased in brightness, and Hγ was seen.. The continuous spectrum in the green was still visible. The dark spaces λ 540, λ 510, and λ 498 were less marked.

On April 1 the magnitude of the star had again increased, being slightly above κ *Persei*, or 4·5 magnitude. Again, as on March 27, an increase in the magnitude of the star was accompanied by a diminution in the brilliancy of the D line; Hα was very bright, and its dark companion was seen. The b band was fainter, and was observed on this night for the last time. The band λ 466 was broader, and so, too, was the bright band still further to the violet, seen first on March 21. The dark spaces λ 510, λ 498, and λ 480 were present though not so distinct.

On April 16 the star was just on the limits of unaided vision,

being glimpsed a few times. It was estimated as less than 36 of Cottam's charts.

A great change had now taken place in the order of brilliancy of the lines, the order being λ 500, Hβ, λ 466, Hα, which was well seen at times, and D, seen only occasionally. Group *b* had disappeared, and the continuous spectrum in the green was of diminished lustre. The dark spaces λ 510, λ 498, and λ 480 were very prominent, partially, no doubt, due to contrast.

On April 19 *Nova* was invisible to the naked eye, and the observation was made through haze and fog. But λ 500 and Hβ seemed to be of equal intensity; D was seen once or twice distinctly, Hα and λ 466 only glimpsed.

On April 21 the magnitude was equal to that of *l Persei*, or 6. The order of brightness was λ 500, Hβ, λ 466, which equalled Hβ at its least refrangible side and faded away towards the violet, D, which was faint, and Hα glimpsed once. The dark space λ 498 was very dark, and λ 480 less so. The continuous spectrum in the green had much brightened.

On April 23 the star rose in magnitude a little above *l*, and the order of brightness in the lines changed to Hα, Hβ, λ 466, λ 500, D. The continuous spectrum in the green still maintained its brilliancy.

On April 24 the star was observed in a hazy sky, but still seemed greater than *l*. The brightest line was λ 500, which was very broad. Then came Hβ, Hα, λ 466, which was brightest at its red side, was very broad, and faded away towards its violet side, and D, seen rarely. The dark spaces λ 510, λ 498, were seen.

On April 25, with the magnitude less than *l*, the order of brightness in the lines of April 16 was resumed, λ 500 being most prominent. The continuous spectrum was weak.

On April 26, with the same magnitude and with perfect seeing, the same order was maintained, except that Hγ was also seen. The D line was excessively faint. Although the continuous spectrum in the green was not very bright, it was present, and details were glimpsed in it beyond the power of the instrument to define. The dark space λ 498 was very pronounced, while λ 510 and λ 480 were well seen.

The chief conclusions to be derived from these details are as follows:

(1) When the star waned on March 25 and 28, the D line and the lines observed in the red and yellow end of the spectrum became bright. On March 27 and April 1, when the star became brighter, D and this part of the spectrum became less brilliant.

(2) The similarity in the order of the brightness of the lines on April 16, 21, 24, 25, 26, is noticeable. But on April 23, the star becoming brighter than on the 21st, the spectrum altered and became almost exactly like that of April 1 and March 27.

(3) The band at about λ 466, first seen on March 21, seemed to be growing relatively brighter and broader, until it became

quite conspicuous on April 16, and remained so, being brighter and sharper at its less refrangible end and diffuse in the opposite direction.

(4) Hα was very bright on March 12, 16, 21; was equal in intensity to Hβ on the 25th; greater than it on the 27th, when it was the brightest of all the lines; equal to it on the 28th; greater than it on April 1; less on the 16th; faint on the 19th and 21st; greater yet again on the 23rd; then less on the 24th, 25th, and 26th, on which last date it was very faint.

(5) The line at about λ 500 on March 21 was not as bright as Hβ; on the 28th became equal to it, faded when the star rose in magnitude on April 1, became greater than it on the 16th, again equalled it on the 19th, became greater on the 21st, less on the 23rd, and the brightest of all the lines on the 24th, 25th, and 26th.

(6) The bright lines shown in this small instrument seem to be coincident with prominent chromospheric lines in the same region of the spectrum.

Stonyhurst College Observatory:
1901 *May* 1.

Further Observations of the New Star in Perseus, made at the Radcliffe Observatory, Oxford.

(*Communicated by Arthur A. Rambaut, M.A., Sc.D., F.R.S., Radcliffe Observer.*)

This paper is a continuation of two others published in the last two numbers of the *Monthly Notices* (pp. 348 to 354 and 390 to 395). It contains the results of the observations of the magnitude and colour of *Nova Persei* made at the Radcliffe Observatory since the last meeting of the Society.

The estimates included in this paper have been chiefly made with telescopic aid, as encroaching twilight and the diminishing altitude of the *Nova* rendered naked-eye estimations increasingly difficult.

In this set of observations the number of comparison stars has been so limited that, to avoid the necessity of frequent reference to the previous papers, their names and index numbers have been set down in Table I. In cases where a telescope has been used an asterisk is affixed to the reference number.

Table II. contains the means of each observer's separate comparisons, and the general mean for each evening.

The accompanying diagram represents graphically the fluctuating changes in the brightness as evidenced by the Radcliffe observations, and is in continuation of a similar diagram printed on page 391 of the *Monthly Notices*. Upon examination of these

two diagrams it will be noticed that the interval between maximum and minimum brightness seems to have undergone a gradual lengthening, but that the range of variation (as far as the breaks in continuity permit us to form an estimate) appears to have changed but little. The greatest range of magnitude during the period under review occurred within an interval of two days only, viz. between April 21 and 23, 6·00 and 4·36 respectively.

The variations in the colour of the star have been noticed by all the observers, and the suggestion made in the last paper that the change in tint was closely related to fluctuations in brightness has been fully confirmed. In each case where the star has been observed near its minimum the colour has been described as increased in redness, and at maximum an orange tint has been usually noticed.

The difficulty of determining the magnitude of the *Nova* by means of comparisons with the neighbouring stars, all of which exhibit a very different quality of colour—which was remarked upon in the previous papers—has been emphasised during the present period by increasing twilight and the fact that but little opportunity is now afforded for observation owing to the rapidly decreasing altitude of the star after sunset.

TABLE I.

List of Stars used for Comparison with Nova Persei.

Ref. No.	Name of Star.	Harvard Photom. Mag.	Ref. No.	Name of Star.	Harvard Photom. Mag.
40	κ Persei	3·95	53	36 Persei	5·40
42	ν Persei	4·00	54	Arg. Z. +44°734	6·04
47	ψ Persei	4·24	55	Arg. Z. +44°648	6·47*
48	σ Persei	4·39	56	Arg. Z. +43°818	5·97
50	l Persei	4·84	57	Arg. Z. +42°754	8·0†
52	30 Persei	5·37	58	Arg. Z. +43°730	7·0†

TABLE II.

Means of Estimations of Magnitude of Nova Persei.

1901.	G.M.T. h m	Observer.	Reference Stars.	Mean Mags.	Adopted Magnitude for the Evening.
April 12	9 30	R.	42, 40, 50	4·70	4·67
	9 45	C.	50, 40, 42	4·63	
13	8 45	R.	42*, 40*, 50*	4·40	4·49
	8 50	W.	50*, 52*	4·75	
	10 0	C.	42, 40, 50	4·40	

* Revision of D.M. † D.M. mag. (Argelander.)

1901.	G.M.T.	Observer.	Reference Stars.	Mean Mags.	Adopted Magnitude for the Evening.
	h m				
April 14	8 55	R.	53, 52, 54	5·50	5·50
	9 40	W.	52*	5·50	
15	9 0	R.	52, 54	5·65	5·82
	9 30	C.	52*, 50*	5·70	
	10 30	W.	52*, 57*	6·40	
16	9 0	R.	52*	5·40	5·32
	10 5	W.	50*, 52*	5·15	
	10 15	R.	52, 50	5·40	
17	7 30	R.	40*, 50*	4·55	4·62
	8 0	R.	50*	4·60	
	9 0	R.	40*, 50*	4·50	
	9 38	W.	50*	4·80	
19	8 23	W.	52*, 50*	5·20	5·13
	8 35	R.	50*, 52*	4·95	
	10 0	C.	52*, 50*	5·25	
20	7 45	R.	56*, 52*	6·00	5·83
	9 0	A.A.R.	52*, 55*	5·95	
	9 0	W.	52*, 55*	5·73	
	9 23	R.	54, 52, 53	5·73	
	9 30	C.	52*, 50*	5·65	
	10 50	C.	55*	6·00	
21	9 0	W.	52*, 55*	6·15	6·00
	9 25	R.	54, 53, 52	5·87	
22	8 23	W.	52*	5·60	5·47
	8 40	R.	52*, 56*	5·55	
	9 0	R.	52*, 56*, 54*	5·50	
	9 8	W.	52*	5·20	
23	9 17	R.	40, 42, 50	4·27	4·36
	9 20	W.	48*, 47*, 40*, 42*, 50*, 40*, 50*	4·47	
	9 20	W.	42, 40	4·50	
	9 38	C.	50*, 40*, 42*	4·27	
24	8 58	W.	52*	5·40	5·08
	9 8	C.	50*, 52*, 40*	4·90	

1901.	G.M.T. h m	Observer.	Reference Stars.	Mean Mags.	Adopted Magnitude for the Evening.
April 25	8 40	W.	54*, 53*, 52*, 55*	5·58	5·86
	9 15	C.	52*, 56*, 55*	6·13	
26	9 52	W.	53*, 52*	5·40	5·55
	10 45	C.	52*, 56*	5·70	
28	8 40	W.	52*, 50*	5·20	5·20
29	9 43	R.	52*, 56*, 50*	5·56	5·56
May 1	7 50	W.	50*, 40*	4·60	5·32
	8 0	R.	52*	5·50	
	8 5	W.	52*	5·50	
	8 37	C.	52*, 50*, 56*	5·37	5·34
	8 43	W.	52*, 50*	5·30	
4	8 53	W.	52*	5·60	5·83
	8 55	C.	52*, 58*, 54*, 56*	6·00	
	9 20	W.	52*, 55*	5·65	
	9 30	W.	52*, 55*	5·75	
6	9 5	R.	52*, 56*	5·70	5·70
	9 8	C.	52*, 56*	5·70	

Magnitudes of Nova Persei.

Observers' Notes on the Estimations of Magnitude.

1901.

Apr. 13. Sky misty, but much fainter stars well seen (W.).

Apr. 14. The Nova seemed fainter than 52 when seen earlier in the twilight (R.)

Apr. 15. With the 1¾-inch the Nova requires a different focus to surrounding stars. Sky very clear (W.).

Apr. 16. Occasionally Nova appeared equal to 52, but brightened up at times and excelled it; the image of Nova was, however, in the 1¾-inch telescope, larger in area than 52 (W.).

Apr. 17. Observed in strong twilight at 7.30 (R.). Sky misty over Perseus (W.).

Apr. 19. Sky is misty, but in the 1¾-inch the small stars between Nova and 50 are easily visible (W.). Difficult to estimate magnitude of Nova to-night, owing probably to slight atmospheric changes; or is it possibly due to rapid physical variations in the object? (R.).

Apr. 20. Differences in colour make the estimation of magnitude very difficult. ½ wt. to 55 (W.).

Apr. 22. Some mist about at 8 23 (W.).

Apr. 23. Moonlight strong, but sky very clear (W.).

Apr. 24. Nova is at times visible to naked eye, but scintillating and vanishing; misty (W.). Thin cloud about; moonlight and twilight troublesome (C.).

Apr. 25. Some twilight and strong moonlight (W.). Estimations difficult; strong moonlight and twilight (C.).

Apr. 26. Nova very low.

Apr. 28. Twilight very strong.

Apr. 29. Nova very low in mist. Estimations difficult. ½ wt. to 50.

May 1. Observed in very strong twilight at 7·50. By setting successively and as rapidly as possible on the three objects, with Mr. Robinson's assistance, I considered, by a single estimate, that, taking 10 steps between 40 and 50, Nova was 7 steps fainter than 40 and 3 steps brighter than 50. As the twilight waned the Nova exhibited a duller light in comparison with the other stars (W.). Twilight rather strong (R.).

May 3. Strong twilight (C.). In the 10-inch Nova required a different focus to the comparison stars (W.).

May 4. Strong twilight (C.). At 9.20 I can just see the stars of 7½ magnitude which lie between Nova and 50 (W.).

Observers' Remarks on Colour of Nova and Comparison Stars.

1901.

Apr. 12. $10^h\ 15^m$. Nova, in Barclay 10-inch, power 90, red, but not very red (R.).

Apr. 13. $8^h\ 30^m$ to $10^h\ 15^m$. Nova, in 10-inch, power 90, red, but not strikingly so (C.). At 8.45 Nova, in Barclay "finder," red, but not very red. No. 40, yellow (R.). With the 1¾-inch, power 20, I noticed at 8.50 a reddish tinge in Nova, but the star was more yellow than on April 10 (W.).

Apr. 14. Nova reddish-yellow in 1¾-inch (W.).

Apr. 15. Nova is very red in the 10-inch: it has an orange centre with ruby fringes (R.).

Apr. 16. Nova, in 10-inch, power 45, is very red (R.). Nova to-night seems to be more red in the 1¾-inch than on Apr. 15 (W.). With 10-inch, power 90, Nova is more red than on Apr. 13 (C.).

Apr. 17. At $8^h\ 0^m$, centre of image of Nova yellow, with very red fringes, in 10-inch, power 45; but in "finder" orange-red only, less red than on Apr. 16 (R.). The Nova was found to be less red at $9^h\ 0^m$ than in the twilight (R.). Nova reddish-yellow in

1901.

Marlborough at 9.0 (W.). The Nova gradually became less red as it sank lower into the mist and cloud; the fringe had nearly disappeared at 10.30 (R.).

Apr. 19. Reddish-yellow in the 1¾-inch (W.). The star was very red in the 10-inch: its redness was maintained during the evening, 7.40 to 10.20 (R.).

Apr. 20. Nova very red in the 10-inch (R.). No. 55 is orange (W.). Nova red in Marlborough (C.).

Apr. 22. Image of Nova red in 1¾-inch (W.). Centre of Nova orange with red fringe in 10-inch; redness not so marked as on Apr. 20, certainly not so much as on Apr. 19 (R.).

Apr. 23. Nova not so red in 1¾-inch, but is a deep orange (W.). Nova less red in Marlborough telescope than on Apr. 20; to the naked eye, stars scintillating greatly (C.).

Apr. 24. The difference of colour of Nova and 52 is very marked. Nova is more red than on 23rd (W.). Nova more red in 10-inch than on 23rd (C.).

Apr. 25. With 1¾-inch Nova is dull reddish; compared with all other stars it appears a "flatter" colour. Much deeper colour and duller than No. 40 (W.). Nova is very red (C.).

Apr. 26. Nova is too low for definite colour observation in the 1¾-inch, but is certainly reddish and dull in contrast to No. 40 and other stars (W.).

Apr. 28. Nova reddish in 1¾-inch (W.).

Apr. 29. Nova very red to-night in 10-inch in contrast to the comparison stars (R.).

May 1. Nova yellowish-red. No. 40 bright yellowish. Nos. 52 and 50, white (W.).

May 3. Nova red in Barclay "finder" (C.). Nova reddish, in strong contrast to 52, in the 10-inch and "finder" (W.).

May 4. Nova very red in the 10-inch (C.).

May 6. Ruby fringes to image of Nova in 10-inch (R.). Very red in 10-inch (C.).

May 8. Caught a glimpse of the Nova in a break at 8.25 in the 10-inch telescope. Could not estimate magnitude, but from the absence of any marked colour I suspect the Nova to be near one of its maxima (R.).

The observers were :	Dr. Rambaut,	indicated by	A.A.R.
	Mr. Wickham,	„	W.
	Mr. Robinson,	„	R.
	Mr. McClellan,	„	C.

Radcliffe Observatory, Oxford:
1901 *May* 9.

*Additional Note on the Position of Nova Persei, and a Comparison of Photographic Magnitudes of Neighbouring Stars with those of Fr. Hagen's Chart and Catalogue.** By F. A. Bellamy, F.R.Met.Soc.

In a former paper (*Monthly Notices*, lxi. p. 340) the position of the *Nova* and comparison stars were based upon the 31 stars in the Bonn A.G. Catalogue +40° to +50° reduced to epoch 1900·0. It will be seen on reference to Table I. (p. 341) that two stars 2972 and 2983 have rather large residuals in R.A., $+0^s.55$ and $+0^s.33$ respectively. These quantities being of the same sign and both the stars coming into the same sides of the equations, east and south halves of the plate, I thought the plate constants might be improved by omitting these two stars, and accordingly obtained these four equations (the computations of ξ' and η' of the Bonn stars, and the means of the Oxford measures being carried to the fourth decimal of the réseau intervals):

$$\begin{array}{lrl} & & x-\xi' & & y-\eta' \\ \text{West half} & 8{\cdot}4362a+13{\cdot}7498b+c= & +1{\cdot}2725 & & +1{\cdot}4199 \\ \text{East half} & 18{\cdot}3311a+13{\cdot}7823b+c= & +1{\cdot}2671 & \text{and} & +1{\cdot}4723 & \ldots\ (A) \\ \text{North half} & 13{\cdot}0493a+18{\cdot}6997b+c= & +1{\cdot}2444 & & +1{\cdot}4426 \\ \text{South half} & 13{\cdot}3658a+9{\cdot}1601b+c= & +1{\cdot}2936 & & +1{\cdot}4476 \end{array}$$

When solved in the usual way the following constants for plate 1728 are obtained:

a	b	c	d	e	f
−·00053	−·00518	+1·3482	+·00530	−·00035.	+1·3800

and the position of the *Nova* becomes

$$\text{R.A. } 1900{\cdot}0 \quad 3^h\ 24^m\ 24^s{\cdot}160 \qquad \text{Dec.} +43^\circ\ 33'\ 42''{\cdot}45 \qquad \xi\ -1{\cdot}7920 \qquad \eta\ -5{\cdot}2585$$

The declination of the *Nova* (*Monthly Notices*, lxi. p. 342) should have been given as $+43^\circ\ 33'\ 42''{\cdot}51$; an error ($0^{r.i.}{\cdot}010$) was made in the very last step of the calculations; the whole of the work has been re-examined, but no other error found. In the former paper the plate constants were obtained with the inclusion of these two stars; for comparison, the equations, constants, and position of the *Nova* are here given.

* Georgetown College Observatory, Washington, 2nd Catalogue and Chart of *Nova Persei* stars.

$$
\left.\begin{array}{ll}
\text{West half} & 8{\cdot}436a + 13{\cdot}749b + c = +1{\cdot}2723 \\
\text{East half} & 18{\cdot}010a + 12{\cdot}932b + c = +1{\cdot}2740 \\
\text{North half} & 13{\cdot}049a + 18{\cdot}699b + c = +1{\cdot}2443 \\
\text{South half} & 13{\cdot}648a + 8{\cdot}904b + c = +1{\cdot}2969
\end{array}\right\} \overset{x-\xi'}{} \text{ and } \left\{\begin{array}{l}
\overset{y-\eta'.}{+1{\cdot}4199} \\
+1{\cdot}4707 \\
+1{\cdot}4427 \\
+1{\cdot}4489
\end{array}\right\} \ldots \quad \text{(B)}
$$

a	*b*	*c*	*d*	*e*	*f*
·00031	−·00539	+1·3491	+·00528	−·00031	+1·3797

	h m s	° ′ ″	ξ	η
Nova 1900·0	3 24 24·12	+43 33 42·3	−1·794	−5·259

The differences, $x-\xi'$ and $y-\eta'$, were entered to the third decimal place for each star, the means of groups being carried to the fourth place. As it might be considered by some that this was insufficiently accurate, I have reformed the equations, entering the x, y, $x-\xi'$, and $y-\eta'$ quantities to the fourth place throughout, and they become

$$
\left.\begin{array}{ll}
\text{West half} & 8{\cdot}4362a + 13{\cdot}7498b + c = +1{\cdot}2725 \\
\text{East half} & 18{\cdot}0100a + 12{\cdot}9323b + c = +1{\cdot}2740 \\
\text{North half} & 13{\cdot}0493a + 18{\cdot}6997b + c = +1{\cdot}2444 \\
\text{South half} & 13{\cdot}6477a + 8{\cdot}9039b + c = +1{\cdot}2970
\end{array}\right\} \text{ and } \left\{\begin{array}{l}
+1{\cdot}4199 \\
+1{\cdot}4706 \\
+1{\cdot}4426 \\
+1{\cdot}4490
\end{array}\right\} \ldots \quad \text{(C)}
$$

The constants found from these are almost identical with (B).

a	*b*	*c*	*d*	*e*	*f*
−·00033	−·00539	+1·3495	+·00527	−·00033	+1·3800

	h m s	° ′ ″	ξ	η
Nova 1900·0	3 24 24·122	+43 33 42·51	−1·7939	−5·2583

A comparison of (B) and (C) seems to show that no sensible increase in accuracy is obtained by extending the calculations to the fourth place of decimals, *which more than doubles the expenditure of time.* A considerably greater change might be made in the constants by the inclusion or omission of a single comparison star (*étoile de repère*) as in (A). This evidence may be of interest to those engaged in the Astrographic Survey.

Passing on to the consideration of the measures of another plate 1732 taken, as before, with the Astrographic Telescope on 1901 March 5 between Oxford sidereal time $6^h\ 24^m\ 40^s$ and $6^h\ 32^m\ 10^s$ with exposures of 1^m, 1^m, 1^m, I will state briefly that each exposure of the thirty-three Bonn stars was measured in D- and R-positions by myself, and the means of these six bisections were taken to four places of decimals; they were then compared with the Oxford standard coordinates ξ' and η' given in Table I. (*Monthly Notices*, lxi. p. 341), the equations formed and solved in the usual way—the two stars 2972 and 2983 being omitted—and the separate stars were corrected for these constants.

In the case of the *Nova*, the diameter of the photographic

image being 30″, three independent bisections of each exposure were made in D- and R-positions of the plate in the measuring instrument, and, similarly, a pair of contact measures were obtained; the means of the eighteen bisections and thirty-six contacts in x and y are

x		y	
Bisections.	Contacts.	Bisections.	Contacts.
r.i.	r.i.	r.i.	r.i.
12·7493	12·7491	9·2708	9·2707

With a view to ascertain if there were any personality in the measurement of large images, *Nova* on this plate was measured in a similar manner by Messrs. H. F. Mullis, B. Gray, and E. A. Gray, with these results:

	x		y	
	Bisections.	Contacts.	Bisections.	Contacts.
H.F.M.	12·7487	12·7499	9·2708	9·2706
B.G.	12·7495	12·7498	9·2692	9·2707
E.A.G.	12·7479	12·7489	9·2698	9·2717

The personality, if any, is very small.

The means in x are 12·7489 for bisections and 12·7494 for contacts, and in y 9·2702 for bisections and 12·2709 for contacts. The equations for plate 1732 are:

$$\left.\begin{array}{ll} \text{West half} & 8{\cdot}2366a + 13{\cdot}8810b + c = +1{\cdot}0728 \\ \text{East half} & 18{\cdot}1309a + 13{\cdot}8117b + c = +1{\cdot}0689 \\ \text{North half} & 12{\cdot}8994a + 18{\cdot}7832b + c = +1{\cdot}0943 \\ \text{South half} & 13{\cdot}1193a + 9{\cdot}2411b + c = +1{\cdot}0491 \end{array}\right\} \text{ and } \left\{\begin{array}{l} y-\eta' \\ +1{\cdot}5512 \\ +1{\cdot}5017 \\ +1{\cdot}5262 \\ +1{\cdot}5283 \end{array}\right.$$

(column heading over the first set: $x-\xi'$)

The constants obtained are

a	b	c	d	e	f
−·00036	+·00473	+·1·0101	−·00500	−·00033	+1·5969

Taking the means of the measures, 216, each in x and y, made by the four measurers, and correcting them for these constants, we get $11^{\text{r.i.}}{\cdot}6998$ for ξ' and $7^{\text{r.i.}}{\cdot}7404$ for η', which, converted into R.A. and Dec., give positions for *Nova* for 1900·0:

R.A. 3$^{\text{h}}$ 24$^{\text{m}}$ 24$^{\text{s}}$·116 Dec. +43° 33′ 41″·79 ξ −1·3002 η −5·2596

By using the same constants for correcting the mean measures of the Bonn stars this table is formed:

TABLE I.

Bonn. A.G.C.	Residuals. x r.i.	x ″	y r.i.	y ″	Bonn. A.G.C.	Residuals. x r.i.	x ″	y r.i.	y ″
2883	·0000	·00	−·0001	−·03	2970	−·0004	−·12	+·0003	+·09
2892	+·0003	+·09	+·0005	+·15	2971	+·0005	+·15	+·0009	+·27
2895	+·0007	+·21	+·0009	+·27	2973	+·0005	+·15	+·0010	+·30
2898	+·0012	+·36	−·0007	−·21	2979	−·0015	−·45	−·0002	−·06
2899	+·0023	+·69	+·0003	+·09	2982	+·0008	+·24	+·0003	+·09
2906	−·0007	−·21	−·0007	−·21	2986	−·0002	−·06	−·0005	−·15
2907	−·0002	−·06	−·0002	−·06	2996	−·0008	−·24	−·0006	−·18
2911	+·0006	+·18	+·0005	+·15	3004	−·0010	−·30	−·0002	−·06
2913	−·0004	−·12	+·0006	+·18	3008	+·0012	+·36	+·0002	+·06
2919	−·0015	−·45	·0000	·00	3009	+·0017	+·51	+·0009	+·27
2944	−·0004	−·12	·0000	·00	3016	−·0015	−·45	·0000	·00
2948	+·0010	+·30	+·0022	+·66	3021	−·0009	−·27	−·0010	−·30
2953	−·0008	−·24	−·0008	−·24	3034	−·0004	−·12	−·0003	−·09
2956	+·0008	+·24	−·0019	−·57	2972	−·0011	−·33	−·0011	−·33
2964	−·0023	−·69	−·0010	−·30	2983	+·0010	+·30	+·0008	+·24
2968	+·0024	+·72	−·0005	−·15					

This table is instructive, as the quantities given are really the differences in the measured positions of the same stars on two plates, and contain all errors in bisections, determination of plate constants, and in the reductions. It may be noticed that the maximum difference in x is less than three quarters of a second of arc, and that there are not more than four stars with differences exceeding half of a second of arc; in the y coordinate there are two instances above a third of a second of arc, but the differences are generally smaller; the mean difference in x without regard to sign is 0″·279, and in y 0″·188. With regard to the last two stars, which have not been included in the reductions, the rather large differences as indicated in the former paper disappear, and those differences cannot be in the measures, but must be either in the Bonn positions or caused by proper motions.

For convenience the places of the *Nova* may be repeated here.

	R.A. 1900·0 h m s	Decl. 1900·0 ° ′ ″
1901 Feb. 25	3 24 24·160	+43 33 42·51
1901 March 5	24·116	41·79

Comparison of Photographic and Visual Magnitudes.

In the former paper no attempt was made to determine the magnitudes of the 159 stars on Argelander or any definite scale, the measured diameter only being given. Since that paper was written Fr. Hagen, of Georgetown College Observatory, has published a second chart and catalogue of faint stars for com-

parison with *Nova* if it should fall below the 7th to the 13th magnitude. In order to ascertain whether all the stars in Fr. Hagen's second catalogue are on plate 1728, and also to gain some information of the estimated as compared with the photographic magnitude, expressed in thousandths of a réseau interval (300″), I have compared the stars in his catalogue with those places obtained from plate 1728, and give the comparison in Table II. Stars No. 1 to 10, 12 to 16, 19, 23, 25–28, 30, 33, 35, 39, 40 are outside the area included in the former Table II. (p. 343).

In making the comparison the position of *Nova* has been taken as $3^h\ 24^m\ 24^s\ +43°\ 33'\ 42''$.

Table II.

B.D. No.	Hagen No.	Oxford No.	H. Mag.	O. Mag.	Difference O–H. R.A.	Difference O–H. Dec.	B.D. No.	Hagen No.	Oxford No.	H. Mag.	O. Mag.	Difference O–H. R.A.	Difference O–H. Dec.
°					s	″	°					s	″
43·734	36	5	9·6	12	− ·5	+43		75	80*a*	12·5	3	− ·7	+10
	43	23	10·2	12	− ·4	+ 6		76	80*b*	12·6	4	− ·3	+14
	45	27	10·4	11	+ ·3	+ 0		74	81*a*	12·4	7	− ·8	+ 2
	46	30	10·7	11	− ·4	+ 1	43·741	29	86	9·2	14	+2·2	+23
	52	31	11·2	8	+ ·3	+ 3		50	89	11·1	7	+ ·2	− 5
	51	32*b*.	11·2	11	·0	+ 5		71?	89*a*	12·3	5	+5·2	+ 3
43·735	34	37	9·6	12	+ ·2	+ 2		66	90	11·9	6	− ·1	− 6
	61	39	11·7	8	+ ·1	+ 5		68	91	12·1	8	−1·1	− 3
	67	40*a*	12·0	5	·0	0		42	92	10·1	12	+ ·6	− 3
	60	42	11·7	9	+ ·3	−18		55	93*a*	11·4	7	+ ·7	+ 9
	63	44	11·9	7	− ·3	− 2	43·743	32	94	9·4	14	+ ·2	− 8
43·737	38	48	9·8	11	+ ·3	− 7		65	93*b*	11·9	5	+ ·6	− 2
	58	50	11·6	7	+ ·1	− 2	43·744	11	98	8·4	24	+ ·9	+ 1
	64	51	11·9	7	+ ·1	+12		47	101	10·7	10	− ·4	−16
	53	55*a*	11·3	9	+ ·7	−10		48	103	10·8	10	·0	+16
43·738	37	57	9·7	9	+ ·6	−16		72	107*a*	12·4	3	−1·1	−13
	49	59	11·0	10	·0	+ 1	43·746	18	108	8·8	20	− ·3	+23
43·739	20	61	8·9	23	+ ·2	+ 1		70	109	12·1	7	·0	− 1
	54	62	11·4	8	+ ·6	− 1		59	111	11·6	8	+ ·4	+ 3
	56	64	11·4	10	−1·6	−23	43·748	24	127	9·0	23	+ ·2	− 4
	57	67*a*	11·6	8	− ·7	+72	43·749	21	132	9·0	15	+ ·2	− 1
43·740	17	68	8·8	21	+ ·6	− 2	43·750	41	137	10·0	14	+ ·2	−18
	44	71	10·3	11	+ ·2	+14	43·751	22	142	9·0	22	− ·3	− 3
	62	73	11·8	8	− ·4	−68	43·752	31	148	9·3	19	+ ·3	+25

Notes.

Hagen No. 29. The difference is rather large; there is a very faint star 4^s preceding, and 45″ north.

No. 51. Only the second exposure measured; the third exposure falls on the réseau line and is invisible.

Nos. 57, 62. No other stars are visible on the plate that would agree more closely.

No. 64. The sign of $\Delta\alpha$ should be *minus*; the chart is correct. A notification of this I have already communicated to the *Astronomische Nachrichten*.

No. 71. Extremely faint, just a trace of the second image; possibly Oxford 89*a* is another star, the other being too faint.

No. 72. Extremely faint, no trace of the second image.

No. 73. If the third and longest exposure is on the plate its place would be on a réseau line; second exposure invisible.

No. 77. Can find nothing to agree with this.

Nos. 74, 75. The second images barely visible, but were not measured; mag. of No. 74 not measured, very diffused image, not like a star; the latter is within the discoloured part of the plate caused by the brightness of *Nova*.

Nos. 69, 78, 79, 80, 81. These are too close to the *Nova* to be seen on the plate, and probably too faint.

The positions of faint stars within 3′ of *Nova* have been determined with the 36-in. telescope at the Lick Observatory (*Publications of the Astron. Soc. of the Pacific*, vol. xiii. p. 65).

As several stars could not be identified with certainty or were not previously measured on the plate, it was examined under the most favourable conditions as to light, and by knowing the positions in which to look for very faint stars. The result of this scrutiny is that every instance of doubt has been removed, except in the case of Hagen's Nos. 71, 73, 77. The identification has not been at all easy owing to other stars being within reasonably close agreement for approximate positions. Father Hagen says his places may be in error by 1^s in R.A. and 36″ in Dec. After some months' experience in comparing Oxford astrographic plates with B.D. stars, the magnitude of the differences, and the frequent uncertainty in deciding which amongst the numerous photographed stars to compare it with, one comes to the conclusion that we are getting too many stars to deal with unless accurate positions are determined; otherwise erroneous identifications will be made.

Nearly all the stars omitted before and now given in this paper (Table III.) are barely visible on the plate, and would easily be overlooked for the reasons just mentioned. For the astrographic work the measurers are generally instructed to pass by and not spend time over any very faint objects which do not show the second image obviously; we are seldom troubled with an insufficiency of stars on our plates, and it seems the better plan to omit doubtful images of stars (? spots in the film) rather than record a large number of spurious places of stars and create perplexities for the future.

The positions of the additional stars with the catalogue number are as below (Table III.).

TABLE III.

Hagen No.	Ref. No.	Oxford Measured Mag.	ξ' 1900·0.	η' 1900·0.	Deduced. R.A. 1900·0. h m s	N. Dec. 1900. ° ′ ″
	16 *a*	6	7·9564	5·6120	3 22 41·22	43 22 58·4
	20 *a*	5	8·2234	5·9673	22 48·50	24 46·9
	32 *a*	5	8·7893	5·7607	23 4·11	23 44·6
51	32 *b*	11	8·9069	8·3660	23 6·95	36 46·5
67	40 *a*	5	9·5845	6·0859	23 25·95	25 23·5
53	55 *a*	9	10·5353	10·8429	23 51·74	47 55·5
57	67 *a*	8	11·4580	10·2804	24 17·29	46 23·6
75	80 *a*	3	12·2855	5·3735	24 40·34	21 52·0
76	80 *b*	4	12·4079	5·5451	24 43·71	22 43·5
74	81 *a*	7	12·4265	8·0682	24 44·16	35 20·4
	84 *a*	6	12·6477	11·8462	24 50·15	54 13·8
71 ?	89 *a*	5	12·8203	6·1291	24 55·16	25 38·8
55	93 *a*	7	13·0268	4·8882	25 0·74	19 26·6
65	93 *b*	5	13·2379	8·6942	25 6·57	38 28·3
	96 *a*	7	13·3804	8·4747	25 10·51	37 22·4
72	107 *a*	3	14·1583	5·6918	25 31·88	23 47·4

As the ordinary photographic plate is not adapted for orange or red coloured stars, it is reasonable to suppose that they would not be on plate 1728, at least if fainter than about the tenth magnitude; this would not tend to agreement in visual and photographic magnitudes.

Grouping the magnitudes in Table II., the following results are obtained for this plate:

TABLE IV.

Limit of Magnitude.	Hagen Mean Mag.	Oxford. Plate 1728.	No. of Stars.
6·5 – 6·9	6·7	33	2
7·0 – 7·4	7·2	36	1
7·5 – 7·9	7·7	32	3
8·0 – 8·4	8·4	25	4
8·5 – 8·9	8·8	21	12
9·0 – 9·4	9·1	18	18
9·5 – 9·9	9·7	11	4
10·0 – 10·4	10·2	12	5
10·5 – 10·9	10·7	10·3	3
11·0 – 11·4	11·2	8·6	7
11·5 – 11·9	11·7	7·7	11
12·0 – 12·4	12·2	5·6	5
12·5 – 12·9	12·6	3·5	2

From which may be derived this *approximate* scale for interpreting the photographic magnitudes given for plate 1728.

Mag.	7·0	7·5	8·0	8·5	9·0	9·5	10·0	10·5	11·2	11·9	12·2	12·6	13·0
Oxford diameter	35	33	29	24	20	15	13	11	9	7	6	5	4

Estimations of Magnitude.

March 25, 7^h. This evening being brilliantly fine, I watched for and noted the time of the first appearance to the eye of some stars of similar magnitude near the *Nova*. At $7^h\ 24^m$ G.M.T. saw ν (3·9 mag.); $7^h\ 28^m$ ι appeared (4·2); $7^h\ 31^m$ Hagen No. 26 and 27 (5·3 and 5·1) were seen, probably as combined light; $7^h\ 32^m$ *Nova* was seen; l (5·1) appeared some minutes before *Nova*. At 8^h *Nova* estimated as $\frac{1}{2}$ magnitude fainter than l. Difference in colour would affect such observations.

March 26, 9^h. Sky very clear, moonlight; *Nova* $= \iota$ and σ *Persei* and $\frac{1}{2}$ magnitude fainter than κ.

April 10. *Nova* intensely red (crimson).

University Observatory, Oxford:
1901 *May* 9.

Further Observations of the New Star in Perseus (3).
By A. Stanley Williams.

The following paper contains a further list of observations of the brightness of *Nova Persei* in the same form as the last one. As, however, the faintness of the star soon rendered greater optical aid necessary, a column has been added to indicate the instrument used. In this Op. signifies opera glass, $\frac{3}{4}$ in. the $\frac{3}{4}$-inch finder attached to a $2\frac{3}{4}$-inch refractor, and $2\frac{3}{4}$ in. the latter instrument itself, with a power of 35. The observations were much hindered by cloud in the early part of April, but the latter half of the month fortunately proved very fine.

Date. 1901.	Greenwich M.T. h m	Observations.	Mag.	Inst.
Apr. 12	9 35	κ Persei + 5, 32 Per. − 1, 36 Per. − 5	4·7	Op.
13	10 20	κ Per. + 2, 32 Per. − 6. 36 Per. − 8	4·35	„
14	8 30	κ Per. + 12, 32 Per. + 5, 36 Per. + 1	5·35	„
	10 10	32 Per. + 4, 36 Per. − 2	5·2	„
15	9 35	32 Per. + 6, 36 Per. + 1	5·45	„
	10 5	36 Per. + 2, 30 Per. + 1	5·55	„
17	9 45	32 Per. + 2, 36 Per. − 3	5·05	„
19	9 45	32 Per. + 5, 30 Per. − 1, = 36 Per.	5·35	„
20	9 40	32 Per. + 6. 30 Per. + 1, = 36 Per.	5·45	„
21	8 50	36 Per. + 3, 30 Per. + 2, = a	5·9	„
		36 Per. + 7, = a	6·3	$\frac{3}{4}$ in.
		36 Per. + 8, a + 2 (see note)	6·25	$2\frac{3}{4}$ in.
	10 0	36 Per. + 2, 30 Per. + 2, a − 2	5·8	Op.

Date. 1901.	Greenwich M.T. h m	Observations.	Mag.	Inst.
Apr. 22	9 15	36 Per. + 5, a − 1	6·15	¾ in.
		36 Per. + 7, a − 3	6·15	2¾ in.
	9 40	36 Per. + 1, a − 3	5·85	Op.
	10 30	= 36 Per. 30 Per. − 1	5·35	„
23	8 38	κ Per. + 1, ν Per. + 5	4·3	„
	8 48	κ Per. + 2, ν Per. + 6, 32 Per. − 10	4·2	„
	8 55	κ Per. + 1, ν Per. + 5, 32 Per. − 8	4·2	„
	9 9	κ Per. + 1, ν Per. + 4	4·2	„
	9 36	κ Per. + 1, ν Per. + 4, 32 Per. − 8	4·15	„
	10 6	κ Per. + 1, ν Per. + 6	4·3	„
	10 28	κ Per. + 1, ν Per. + 4	4·2	„
24	9 15	36 Per. + 7, a − 7	5·95	2¾ in.
	9 25	36 Per. + 6, a − 4	6·05	¾ in.
25	9 17	36 Per. + 7, a − 2·7	6·2	2¾ in.
26	9 8	36 Per. + 8, a − 3	6·2	„
28	9 0	= 36 Per. a − 10	5·45	„
May 2	8 50	About 1 mag. brighter than 36 Per.	4·4 ±	„
3	8 45	36 Per. + 1·5, a − 9·5	5·55	„
4	8 45	36 Per. + 9, a − 2	6·3	„
5	8 36	36 Per. + 8, a − 3	6·2	„
6	8 35	36 Per. + 10, a − 1	6·4	„

Notes.

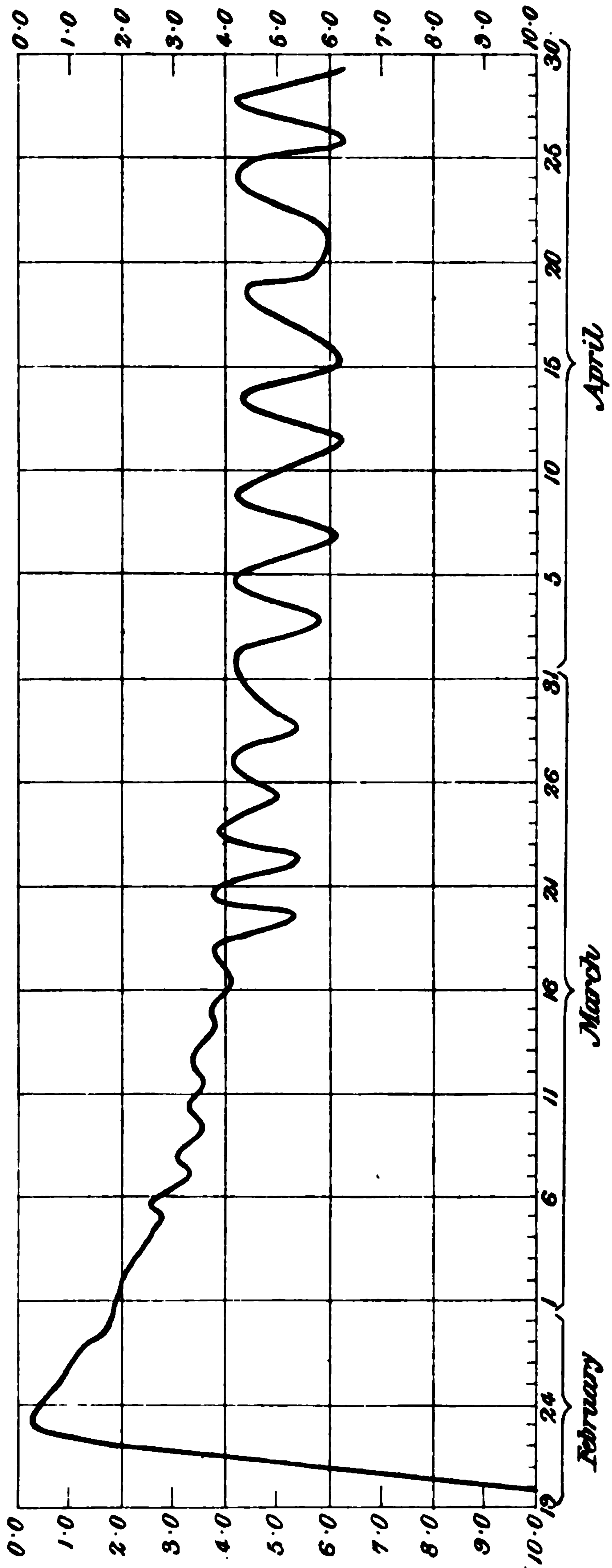
April 12, a little hazy but no cloud. April 13, slight mistiness may just possibly have affected the estimates. April 14, very clear. April 15, very clear. April 17, hazy. April 19, a little hazy towards horizon, otherwise clear. April 20, very clear, *Nova* just steadily visible in opera glass. April 21, exceedingly clear. A note to the last estimate made the same night runs, "I feel *sure* this should be $a-2$," instead of $a+2$. April 22, very clear. April 23, very clear except at commencement and end of the series, when slightly hazy. April 24, hazy. April 25, clear. The observations as given are the means of three separate sets of comparisons between $9^h\ 10^m$ and $9^h\ 25^m$. April 26, very clear, but some cloud about. Three sets of comparisons between $9^h\ 0^m$ and $9^h\ 18^m$. April 28, clear night. Good observations from many repeated comparisons. May 2, hazy and sky very bright, so impossible to make a satisfactory estimate. The star was invisible in the opera glass, and owing to a counterpoise coming in contact with one of the legs of the stand, it could not be followed long enough to make comparison with brighter stars, such as κ and ν *Persei*. The brightness of the *Nova* on this night is, however, certain. It was incomparably brighter than the star *a*, and a whole magnitude brighter than 36 *Persei*. May 3, very clear. Mean of two sets of comparisons between $8^h\ 40^m$ and $8^h\ 50^m$. May 4, hazy, but observations fairly satisfactory. May 5, clear. Mean of four sets of comparisons between $8^h\ 30^m$ and $8^h\ 43^m$. May 6, very clear. Mean of three sets of comparisons between $8^h\ 30^m$ and $8^h\ 41^m$.

The comparison star designated *a* in the above observations is the 6·5 magnitude star B.D. + 44°·734. It will be seen that there have been some further remarkable fluctuations in the brightness of *Nova Persei*, and of a type apparently differing somewhat from that of the changes which occurred in March. In that month the normal condition of the star as seen here seems to have been bright, with well marked and rather accentuated minima at intervals of three or four days. But in April–May the star has appeared normally faint, with at intervals well marked and accentuated maxima. The observations show that the star was unusually bright on April 13, 17, 23, and 28, and on May 2. The maxima of April 23 and May 2 are specially remarkable. On the former of these two dates the star appeared nearly two whole magnitudes brighter than it had been the previous night. So striking was the change that observations were repeated at intervals to see if the star was still varying. There was no certain change, however, in the interval of $1^h\ 50^m$ over which the observations extended, although by the following night the star had sunk again to 6·0 mag. On May 2 the rise seems to have been nearly as great as it was on April 23. The conditions were very unfavourable on this night, but I feel sure, notwithstanding, that the *Nova* was a full magnitude brighter than 36 *Persei*, or about 4·4 mag. It is easy to trace a rough periodicity in the above dates of maxima, but observations from the other hemisphere seem necessary for the satisfactory discussion of such a question.

The observations made with different instruments at the same time on one or two nights, April 21 in particular, present some rather curious differences, and it would seem that the opera-glass is not a suitable instrument for noting slight differences of brightness in stars nearly at the limit of visibility. Under such conditions the value of a step seems to be markedly greater with the opera-glass than it is with either the ½-inch or 2¾-inch telescopes, and the estimates correspondingly rougher.

The following observations of the colour of the *Nova* were made with p. 75 on the 2¾-inch refractor. April 12, fairly deep reddish at $9^h\ 35^m$, but at $9^h\ 55^m$ white without any decided red tinge. April 15, flaming red, a very bright intense red colour. April 19, very intensely red (crimson). April 20, crimson, pretty deep in flashes, though not quite as intense as on the previous night. April 21, reddish, not at all deep or marked. April 22, reddish, not at all deep or marked. April 23, white or slightly yellowish, with pale reddish flashes. The red colour not at all marked and not *nearly* so deep as it was a few nights earlier. At times, indeed, there seemed to be distinct bluish flashes. April 24, very deep intense red. April 26, very red.

The almost complete absence of red colour on April 23 is rather remarkable, since the star was then at a maximum of brightness. On April 24 the *Nova* had fallen to the 6th mag. and



Light Curve of Nova Persei 1901.

had again become intensely red. This would seem to indicate a connection between the variations of brightness and colour. However, it should be noted that both on April 21 and 22, when the star was faint, the red colour was not at all deep or marked.

Hove: 1900 May 8.

Light Curve of Nova Persei, 1901. By Laurence Child.

(*Communicated by Rev. Edmund Ledger.*)

The curve (plate 13) is the mean of 527 observations. I have obtained the data from observations made by Miss Orr and myself, together with those published in the *Ast. Nach.* and the *Bulletin de la Soc. de France.* The only day without observations is April 24, so that the magnitude of the maximum on that day is only surmised.

The dates of maxima and minima are as follows:—

		Minima.			Maxima.
March	19		March	20	
	22	Very red		23	
	25	Red		27	Orange
	28	Red	April	1	Orange
April	2	Red		4	
	7	Red		9	
	11	Red		14	
	15	Red		19	Orange
	21	Red		24	
	25	Very red		27	

Vernham, Merton Hall Road, Wimbledon.

Further Observations of Nova Persei. By M. C. Sharp.

The following list of estimated magnitudes is rather short, cloudy weather and pressure of other occupations having somewhat curtailed opportunities:

April	12	4·7	April	20 ($10^h\ 40^m$)	5·6
„	13	4·4	„	21	5·7
„	14	5·3	„	22 ($8^h\ 48^m$) ...	5·5
„	15	5·6	„	„ ($10^h\ 15^m$)	5·2
„	18	4·1	„	25	6·0
„	19	5·4	May	3	5·8
„	20 ($9^h\ 45^m$) ...	5·8	„	4	6·6(?)

At the time of the second observation on April 20 the sky was rather clearer than at the earlier hour. On April 22 at 8.48 there was still some twilight, and this probably accounts partly for the apparent rise in magnitude. On May 4 the moonlight and haze obliterated the fainter stars in the binocular. D.M. 46°·760, which was used as a comparison star, is rated at 6·5 in the Durchmusterung, but certainly appeared brighter as judged by other stars near which were visible.

1901 *May* 9.

The Green Flash at Sunset. By J. Franklin-Adams.

A series of notes as to the green flash at sunset suggests that time spent upon careful observation of this phenomenon would be amply repaid; not much more seems to be known about it than the fact that at a particular moment—when the Sun's image is disappearing below the sea horizon—a flash of brilliant green is in a clear sky visible to the naked eye during a fraction of a second.

With a little optical help—that, for instance, of a Zeiss prismatic field glass—it will be found that the green display continues for nearly three seconds.

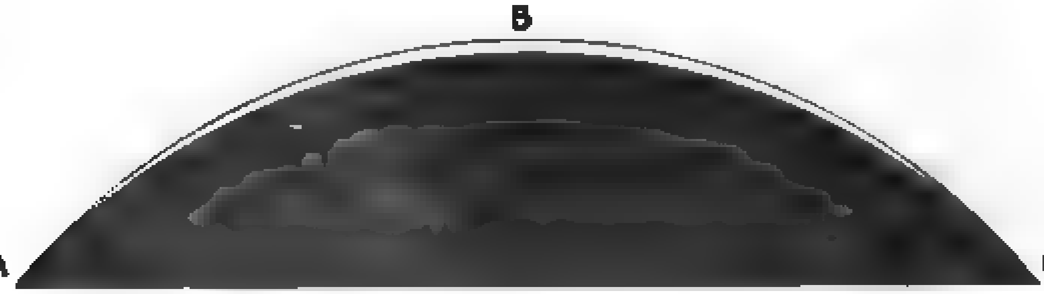


Fig. 1.

The object of this communication is to give some details of an observation made here on April 19 of this year. The Sun set in a manner exceptionally favourable for observing the green flash: sky quite clear, and without any trace of haze or mist even near the horizon.

The green flash first appeared in the shape of a single brilliant emerald bead, then another, and a third, and in about a second a full display of Baily's beads had developed in much the same way as in a solar eclipse, but to a much smaller extent and for a much shorter time. The first bead I noticed was towards the S. point of the horizon, the others close towards the N., until my eye reached the fourth, when I found a string of about seven beads. My idea is that they would form at either end of the segment D E F, fig. 2, and join on the middle of the row, but my

surprise at the sight of Baily's beads without an eclipse was so great that I did not notice this point.

I beg to submit that it would be interesting if careful observers by the seaside—or at sea—during the summer would send any results to the secretaries or to myself. Especially would I ask for sunrise observations of the flash. Astronomers after a night's work seldom sit up until sunrise, but on board ship it is easy to arrange to be called just before sunrise.

It has been suggested to me that if, as has been more or less accepted hitherto, Baily's beads owe their origin to the mountains and valleys in the Moon, the phenomenon here described may have been caused by the waves of the sea taking the place of the mountains of the Moon. The evening was calm, and the waves not large enough to make this possible unless images of the waves were thrown up by a mirage state of the atmosphere. I have twice seen from a steamer's deck mirage images of the sea waves, about a mile distant, thrown up sufficiently to entirely hide the horizon.

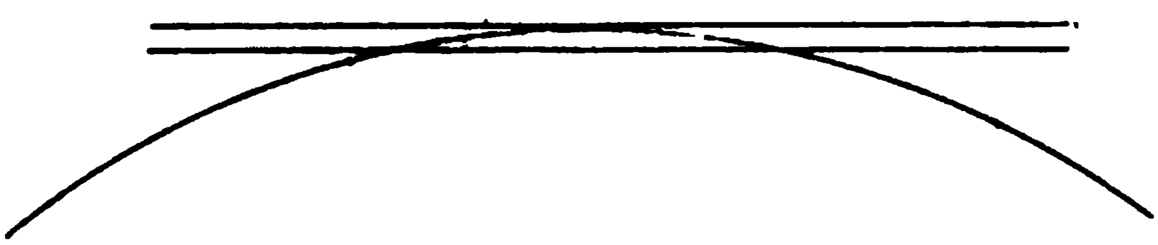


Fig. 2.

I add some further details and some diagrams. Time occupied in fully developing about one and a half seconds, and the same in disappearing. Time was estimated by counting aloud and not by chronograph. Length of bead display in measure of Sun's diameter about one-twelfth—this is very uncertain. Colour of beads emerald green with a slightly bluish tinge. Fig. 1 shows a Moon of 32′ eclipsing a Sun of 31′. Fig. 2 shows the extreme diametrical measure of the crescent A B C, fig. 1, being occulted by the straight line of the sea horizon. Fig. 3 shows an estimate of the proportionate size of the beads, drawn for the sake of clearness on a scale about four times that of figs. 1 and 2.

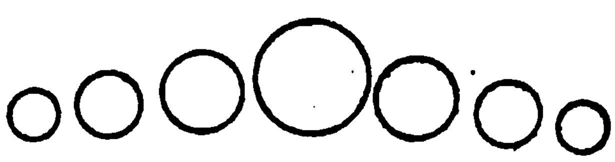


Fig. 3.

Endeavour will be made here during the summer, when our long twilight stops stellar photography, to photograph some flashes through colour screens or filters and to take chronographic measurements of their duration.

Machrihanish, Argyll'shire: 1901 April.

M M

Results of Micrometer Measures of Double Stars made with the 28-inch Refractor at the Royal Observatory, Greenwich, in the year 1900.

(*Communicated by the Astronomer Royal.*)

The measures were made with a bifilar position-micrometer on the 28-inch refractor, aperture 28 inches, focal length 28 feet. The power generally used was 670, but when the definition permitted a power of 1120 was employed for observing very close pairs. A blue glass shade was employed to diminish the light and irradiation when bright stars were observed. The observations were made in variously coloured fields or in a dark field with illuminated wires. The initials in the last column are those of the observers, viz. :—

B. Mr. Bryant L. Mr. Lewis W.B. Mr. Bowyer

The observations of *Capella* have already appeared in the *Notices* of the Society for 1900 June and December, and hence are not included in the present paper.

Micrometric Observations of Double Stars.

Star's Name.	R.A. 1900. h m	N.P.D. 1900. ° ′	Position Angle °	Distance. ″	No. of Meas.	Mags.	Epoch 1900.	Obs.
Σ 3062 ...	0 1	32 10	341·8	1·50	1	6·9 8·0	·066	B.
β 253 ...	0 5	32 2	49·7	0·43	1	8·3 8·4	·066	B.
Krueger 1 ...	0 6	32 43	188·7	2·01	1	9·1 9·2	·066	B.
β 1026 ...	0 7	36 56	330·9	0·37	1	8·1 8·9	·066	B.
OΣ 2 A.B. ...	0 8	63 35	38·2	0·52	2	6·5 8·0	·033	B.
			37·3	0·49	1	...	·041	L.
OΣ 4 ...	0 10	54 4	100·6	0·23	2	7·4 8·1	·948	B.
β 1027 ...	0 10	69 3	180·1	1·40	1	7·7 10·5	·041	L.
			184·1	1·44	1	...	·747	W.B.
β 1093 ...	0 15	73 36	59·1	0·31	2	7·3 8·2	·493	B.
OΣ 12 (λ Cassiopeiæ)...	0 26	36 8	145·0	0·37	1	5·0 6·0	·066	B.
OΣ 15 ...	0 30	41 32	320·5	0·17	1	7·5 8·5	·964	B.
β 257 ...	0 35	43 17	234·5	0·49	1	8·1 8·8	·964	B.
β 865 ...	0 38	47 20	195·9	1·11	1	8·3 8·8	·964	B.
β 866 ...	0 40	47 20	70·8	1·54	1	9·1 9·1	·964	B.
β 495 ...	0 42	71 52	225·6	0·57	2	7·6 7·7	·033	B.
β 232 ...	0 48	39 55	320·1	0·44	1	8·0 8·1	·964	B

Star's Name.	R.A. 1900. h m	N.P.D. 1900. ° ′	Position Angle. °	Distance. ″	No. of Meas.	Mags.		Epoch 1900.	Obs.
OΣ 20 ...	0 49	71 22	327·9	0·33	1	5·9	7·0	·022	B.
			314·1	0·48	2	...		·931	W.B.
Σ 73 (36 Andromedæ)	0 49	66 55	19·1	0·90	4	6·2	6·8	·853	W.B.
OΣ 21 ...	0 57	43 10	29·5	0·97	1	6·9	8·2	·964	B.
β 303 ...	1 4	66 44	286·1	0·64	2	7·2	7·5	·033	B.
			291·5	0·62	1	...		·991	W.B.
β 4 ...	1 18	79 9	65·7	0·33	1	7·8	8·8	·022	B.
β 1164 ...	1 22	85 10	168·8	0·33	1	6·7	7·0	·022	B.
β 506 (η Piscium)	1 26	75 10	14·5	1·16	1	4·0	10·5	·047	L.
Σ 138 ...	1 30	82 52	220·7	1·45	1	7·3	7·3	·044	B.
			217·6	1·43	1	...		·047	L.
Σ 155 ...	1 35	8 34	328·9	4·53	1	7·5	7·9	·047	L.
β 509 ...	1 38	80 56	268·7	0·69	1	8·4	8·7	·047	L.
			254·5	0·61	1	...		·931	B.
Σ 158 ...	1 41	57 20	259·7	1·91	1	8·3	8·8	·047	L.
			257·2	2·06	1	...		·099	B.
β 1016 ...	1 44	57 25	23·3	0·48	1	8·5	8·5	·047	L.
			26·1	0·51	1	...		·099	B.
β 235 ...	1 45	39 30	94·7	0·81	2	7·0	7·5	·504	B.
Hough 311	1 45	65 50	178·8	0·30	1	7·5	7·7	·964	B.
Σ 205 (γ^1 Andromedæ)	1 58	48 10	62·2	9·76	1	3·0	5·0	·041	L.
OΣ 38 (γ^2 Andromedæ)	1 58	48 10	114·8	0·40	2	5·0	6·2	·127	L.
Σ 208 ...	1 58	64 33	53·9	0·77	1	6·2	8·4	·958	W.B.
Hough 497	2 6	53 7	62·6	0·53	1	8·2	9·0	·041	L.
Σ 228 ...	2 8	42 59	94·2	0·55	1	6·7	7·6	·192	L.
			82·7	0·55	1	...		·964	B.
Σ 257 ...	2 18	28 55	248·5	0·37	1	7·2	7·7	·192	L.
OΣ 42 ...	2 27	38 8	121·0	0·40	1	7·0	7·5	·192	L.
OΣ 44 ...	2 36	47 44	56·8	1·33	1	7·8	8·5	·099	B.
Σ 305 ...	2 42	71 2	317·0	2·92	1	7·3	8·2	·022	B.
			313·1	3·10	3	...		·945	W.B.
β 262 ...	2 42	59 22	62·4	1·56	1	8·2	9·6	·947	W.B.
β 525 ...	2 53	52 31	137·4	0·20	1	7·5	7·5	·104	W.B.
Σ 333 ... (ε Arietis)	2 53	69 4	201·7	1·28	2	5·7	6·0	·965	W.B.
Σ 346 A.B.	3 0	65 8	93·8	0·45	2	6·0	6·0	·544	W.B.

Star's Name.	R.A. 1900. h m	N.P.D. 1900. ° ′	Position Angle. °	Distance. ″	No. of Meas.	Mags.	Epoch 1900.	Obs.
			87·6	0·56	2	...	·553	B.
A.C.	...	...	351·1	5·21	1	...	·104	W.B.
β 1030 ...	3 4	68 39	155·7	0·53	1	8·4 8·4	·989	L.
β 530 ...	3 8	67 25	188·4	1·78	1	9·7 10·1	·980	L.
OΣ 53 ...	3 11	51 44	236·6	0·59	1	7·2 8·0	·142	B.
			238·2	0·58	1	...	·192	L.
β 533 ...	3 29	58 39	44·0	0·30	1	7·0 7·0	·104	W.B.
			50·4	0·57	1	...	·142	B.
Σ 412 ... (7 Tauri)	3 28	65 52	13·8	0·15	1	6·6 6·7	·104	W.B.
			13·9	0·27	1	...	·964	B.
OΣ 66 ...	3 45	49 30	139·4	0·48	1	7·5 8·0	·142	B.
			132·2	0·43	1	...	·192	L.
β 880 ...	3 38	58 9	1·8	0·62	1	8·7 8·9	·192	L.
OΣ 531 ...	4 1	52 12	128·3	2·07	1	8·5 10·2	·142	B.
OΣ 77 ...	4 9	58 34	178·0	0·22	1	7·0 7·5	·118	B.
OΣ 80 ...	4 17	47 46	189·7	0·48	1	6·5 7·0	·142	B.
			176·3	0·50	1	...	·203	W.B.
			173·9	0·60	1	...	·939	L.
Σ 535 ...	4 18	78 53	327·9	1·49	1	6·7 8·2	·022	B.
			320·2	1·36	1	...	·126	W.B.
β 550 ... (Aldebaran)	4 30	73 42	109·0	31·29	2	1 14	·131	L.
Hastings ...	4 30	70 29	55·6	0·36	1	8·0 9·0	·068	W. B.
OΣ 86 ...	4 31	70 27	60·8	0·55	1	7·5 7·5	·137	W.B.
Σ 567 ...	4 31	70 44	320·8	1·68	1	8·5 9·0	·947	W.B.
Σ 572 ...	4 32	63 16	19·6	3·86	1	6·5 6·5	·947	W.B.
β 883 ...	4 45	79 6	60·4	0·26	3	7·5 7·5	·146	L.
			62·6	0·27	1	...	·186	B.
			63·3	0·27	6	...	·211	W.B.
β 552 ...	4 46	76 31	207·9	0·45	2	6·9 10·2	·193	L.
OΣ 93 ...	4 55	85 3	51·3	0·74	2	7·5 9·0	·164	B.
OΣ 98 ...	5 2	81 39	174·4	0·98	2	5·5 7·0	·164	B.
			170·4	0·73	1	...	·214	L.
β 1047 ...	5 3	62 5	53·3	0·45	1	8·5 8·8	·214	L.
β 885 ...	5 6	91 54	25·8	0·56	1	8·3 8·4	·186	B.
β 1006 ...	5 7	92 19	204·1	0·51	1	8·5 10·9	·186	B.
β 886 ...	5 15	56 17	243·7	1·18	1	9·1 9·6	·300	L.
OΣ 105 ...	5 16	77 26	106·5	0·30	1	7·8 7·8	·186	B.

Star's Name.	R.A. 1900. h m	N.P.D. 1900. ° ′	Position Angle. °	Distance. ″	No. of Meas.	Mags.	Epoch 1900.	Obs.
Dawes 5 ...	5 19	92 29	81·4	1·24	1	3·5 5·5	·164	B.
Σ 719 ...	5 24	60 32	322·5	0·90	1	7·0 9·5	·104	W.B.
Σ 728 ...	5 26	84 7	188·8	0·38	2	5·5 6·5	·175	B.
Σ 749 ...	5 31	63 8	173·6	0·77	1	7·1 7·2	·104	W.B.
			174·8	0·91	3	...	·164	B.
β 1240 A.B.	5 32	59 34	346·4	0·28	1	5·6 6·0	·203	W.B.
Σ 753 A.C.			267·8	12·53	1	...	·203	W.B.
OΣ 112 ...	5 33	52 6	73·4	0·52	3	7·5 7·5	·190	B.
			68·1	0·55	1	...	·192	L.
β 1007 ...	5 35	73 31	254·7	0·20	2	6·0 6·2	·214	B.
Σ 774 ...	5 36	92 0	155·7	2·41	2	2·0 5·7	·175	B.
OΣ 118 ...	5 42	69 10	314·0	0·48	2	8·0 8·8	·173	W.B.
			312·2	0·54	1	...	·238	L.
Σ 799 ...	5 45	51 28	180·4	0·95	3	7·2 8·3	·190	B.
			180·8	0·85	1	...	·192	L.
Perrine ...	5 51	37 19	307·1	1·92	1	9·0 9·8	·255	L.
β 1241 ...	6 4	66 52	345·8	0·45	1	5·9 10·0	·238	L.
			329·2	0·41	1	...	·241	B.
β 1058 ...	6 4	66 59	276·8	0·36	1	7·2 7·5	·183	W.B.
			276·5	0·30	2	...	·214	B.
			268·3	0·25	1	...	·238	L.
*	6 8	67 24	87·6	2·99	1	9·5 10·0	·238	L.
β 1008 ...	6 9	67 28	296·6	0·88	1	3·0 10·8	·238	L.
Σ 881 ...	6 13	30 35	108·3	0·65	1	6·4 7·9	·307	L.
β 895 A.B.	6 14	61 31	150·7	0·24	1	8·2 8·4	·241	B.
Σ 888 A.C.	...	...	251·3	2·60	1	8·2 9·2	·241	B.
β 1020 ...	6 17	61 11	155·1	1·09	1	8·2 10·0	·104	W.B.
			164·4	1·10	1	...	·238	L.
Σ 899 ...	6 17	72 22	19·8	2·31	2	7·0 8·0	·115	W.B.
β 1192 ...	6 23	69 43	340·6	0·16	1	8·7 8·8	·241	B.
β 1021 ...	6 25	61 33	80·6	0·79	1	8·1 9·4	·238	L.
			78·4	0·55	1	...	·241	B.
Σ 932 ...	6 29	75 10	328·0	2·15	1	8·2 8·3	·047	L.
			324·6	1·94	1	...	·104	W.B.
OΣ 149 ...	6 30	62 38	274·8	0·66	2	6·5 9·0	·143	L.
			282·7	0·45	1	...	·241	B.
Σ 396 ...	6 31	31 48	263·2	1·66	1	7·0 8·7	·307	L.
Σ 945 ...	6 33	48 56	270·0	0·71	2	7·1 8·0	·177	B.
			260·9	0·78	1	...	·255	L.

Star's Name.	R.A. 1900.	N.P.D. 1900.	Position Angle.	Distance.	No. of Meas.	Mags.	Epoch 1900.	Obs.
	h m	° ′	°	″				
*	6 34	...	80·0	2·03	1	...	·255	L.
Σ 948 A.B.	6 37	30 28	114·8	1·48	2	5·2 6·1	·623	L.
OΣ 156 ...	6 41	71 42	301·1	0·53	4	6·5 7·0	·123	B.
			305·9	0·49	2	...	·143	L.
OΣ 160 ...	6 48	68 43	171·9	1·52	1	6·8 9·8	·049	L.
β 899 ...	6 53	71 9	266·6	0·60	1	8·7 9·3	·044	B.
			274·1	0·60	1	...	·236	L.
β 900 ...	7 0	68 49	273·7	1·41	1	8·0 11·5	·236	L.
OΣ 165 ...	7 3	73 54	42·5	4·17	1	5 11	·236	L.
Σ 1037 ...	7 7	62 35	302·5	0·77	1	7·0 7·1	·301	L.
			302·1	0·75	1	...	·309	B.
β 1023 ...	7 9	63 56	294·5	0·19	1	8·4 8·5	·241	B.
			291·5	0·34	1	...	·301	L.
*	7 9	63 56	226·5	0·72	1	9·5 10·0	·241	L.
OΣ 170 ...	7 14	80 31	110·7	1·56	3	7·0 7·5	·084	B.
Σ 1110 ...	7 28	57 53	225·2	5·71	1	2·7 3·7	·183	B.
			226·4	5·95	1	...	·192	L.
OΣ 175 ...	7 29	58 50	330·1	0·66	3	6·0 6·6	·083	B.
			329·0	0·71	1	...	·192	L.
OΣ 176 ...	7 33	89 14	200·0	1·56	1	7·3 7·3	·044	B.
Σ 1126 ...	7 34	84 28	144·2	0·81	2	7·0 7·0	·225	L.
			142·7	1·07	1	...	·233	B.
OΣ 177 ...	7 35	52 19	120·2	0·50	4	7·5 8·5	·123	B.
			119·3	0·59	1	...	·120	L.
Procyon ...	7 35	84 28	338·3	4·83	1	1 10	·236	L.
Σ 963 ...	7 44	30 26	69·5	0·51	1	5·9 7·1	·306	L.
OΣ 182 ...	7 47	86 20	30·8	1·16	2	7·0 7·5	·115	B.
Σ 1157 ...	7 49	92 31	62·8	1·10	1	8·0 8·0	·233	B.
OΣ 185 ...	7 52	88 35	13·5	0·30	2	6·8 7·1	·139	B.
β 581 ...	7 59	77 25	284·8	0·53	2	8·5 8·6	·284	L.
			286·1	0·35	3	...	·187	B.
Σ 1184 ...	8 3	51 49	341·2	26·82	1	8·0 8·5	·047	L.
			341·4	27·06	1	...	·329	B.
Σ 1187 ...	8 3	57 28	45·5	2·17	1	7·1 8·0	·047	L.
			41·8	2·00	1	...	·309	B.
Σ 1196 A.B. (ζ Cancri)	8 6	72 3	5·8	1·08	2	5·0 5·7	·237	B.
A.C.	...	...	113·6	5·10	2	5·0 6·5	·237	B.
B.C.	...	...	125·7	5·64	1	5·7 6·5	·241	B.

Star's Name.	R.A. 1900. h m	N.P.D. 1900. ° ′	Position Angle. °	Distance. ″	No. of Meas.	Mags.		Epoch 1900.	Obs.
Σ 1211 ...	8 12	50 42	130·6	0·95	1	8·7	9·2	·329	B
β 209 ...	8 37	50 50	358·3	1·39	2	8·2	8·7	·319	B.
Σ 1273 (ε Hydræ A.C.)	8 41	83 13	229·8	3·53	1	3·8	7·7	·236	L.
			230·2	3·43	1	...		·298	W.B.
Schiaparelli (ε Hydræ A.B.)	...	...	267·2	0·20	1	3·8	6·0	·236	L.
β 1068 ...	8 44	88 46	185·9	0·45	1	7·7	8·8	·241	B.
Σ 3121 ...	9 12	61 0	18·3	0·80	2	7·5	7·8	·258	L.
			18·9	0·89	1	...		·241	B.
			22·6	0·57	1	...		·263	W.B.*
OΣ 201 ...	9 18	61 39	222·7	1·41	2	7·5	9·0	·281	W.B.
			220·1	1·31	1	...		·301	L.
Σ 1348 ...	9 19	83 13	322·0	1·72	1	7·5	7·6	·312	W.B.
Σ 1356 ...	9 23	80 31	112·0	0·66	3	6·2	7·0	·261	B.
			114·3	0·62	1	...		·312	B.
OΣ 208 ...	9 45	35 28	281·4	0·18	1	5·0	5·6	·315	L.
			284·7	0·27	2	...		·367	B.
Σ 1389 ...	9 47	62 31	308·9	2·13	2	8·2	9·0	·334	W.B.
A.C. 5 ...	9 47	97 38	84·2	0·27	1	5·5	5·7	·233	B.
OΣ 215 ...	10 11	71 46	206·0	0·65	1	7·0	7·2	·236	L.
			210·1	0·91	2	...		·237	B.
Σ 1424 (γ Leonis)	10 14	69 39	118·3	3·67	1	2·0	3·5	·236	L.
			115·3	3·29	1	...		·427	B.
Σ 1426 A.B.	10 15	83 4	279·0	0·73	2	7·8	8·3	·275	B.
			278·0	0·64	1	...		·312	W.B.
A.C.	...	...	8·0	7·58	1	7·8	9·2	·312	W.B.
OΣ 216 ...	10 17	74 9	118·3	1·11	1	7·0	10·5	·236	L.
			116·5	1·33	1	...		·241	B.
Σ 1429 ...	10 20	64 53	252·2	0·75	1	8·3	8·3	·236	L.
			257·2	0·96	2	...		·305	W.B.
			249·0	0·97	1	...		·309	B.
OΣ 217 ...	10 21	72 16	157·0	0·62	1	7·3	7·8	·236	L.
			153·9	0·73	2	...		·237	B.
Σ 1457 ...	10 34	83 45	318·5	1·28	1	7·4	8·8	·309	B.
OΣ 225 A.B.	10 35	70 14	246·2	0·81	1	7·5	11·2	·345	W.B.
A.C.	...	...	345·7	6·51	1	7·5	9·8	·345	W.B.

* Quadrant certain.

Star's Name.	R.A. 1900.	N.P.D. 1900.	Position Angle.	Distance.	No. of Meas.	Mags.	Epoch 1900.	Obs.
	h m	° ′	°	″				
OΣ 227 ...	10 36	78 44	349·4	0·48	1	7·5 8·5	·309	B.
			349·5	0·47	1	...	·312	W.B.
OΣ 228 ...	10 42	66 54	192·3	0·45	2	7·2 8·1	·271	B.
			191·2	0·49	2	...	·294	W.B.
OΣ 229 ...	10 42	48 21	317·5	0·80	2	6·7 7·1	·368	B.
β 915 ...	10 44	65 11	232·3	1·85	1	9·0 9·0	·315	L.
			234·1	1·46	1	...	·345	W.B.
Hough 48 ...	10 59	66 18	125·5	1·51	1	8·3 11	·290	W.B.
Σ 1504 ...	10 59	85 47	289·6	1·13	1	7·4 7·5	·209	B.
Hough 378...	10 59	51 2	228·6	0·33	1	8 8·1	·309	B.
Σ 1517 ...	11 9	69 19	272·4	0·35	2	7·3 7·3	·271	B.
			268·1	0·42	2	...	·293	W.B.
Σ 1523 (ξ Ursæ Maj.)	11 13	57 54	155·5	2·30	1	4·0 4·9	·301	L.
			151·7	2·17	2	...	·368	B.
Σ 1524 (ν Ursæ Maj.)	11 13	56 22	147·4	7·73	1	3·7 10·1	·301	L.
			147·4	7·37	1	...	·309	B.
Σ 1534 ...	11 16	71 14	324·7	5·09	1	8·0 11·0	·290	W.B.
Lalande 21846	11 24	58 57	6·7	0·94	1	7·0 11·0	·301	L.
			6·0	0·84	1	...	·312	W.B.
OΣ 234 ...	11 26	58 1	309·4	0·26	1	7·0 7·4	·427	B.
OΣ 235 ...	11 27	28 22	120·9	0·58	1	6·0 7·3	·427	B.
Σ 1554 ...	11 31	76 36	259·9	0·86	2	8·9 9·1	·329	W.B.
Σ 1555 ...	11 31	61 40	347·3	0·37	2	6·4 6·8	·294	W.B.
			347·0	0·38	2	...	·352	L.
			354·7	0·27	1	...	·309	B.
β 603 ...	11 45	75 5	315·6	0·84	1	6·4 10·3	·435	L.
Σ 1606 ...	12 5	49 31	325·8	0·97	1	6·2 7·0	·427	B.
Σ 1639 ...	12 19	63 52	173·7	0·23	3	6·7 7·9	·300	W.B.
			180·1	0·15	3	...	·340	L.
Σ 1643 ...	12 22	62 25	38·1	2·02	3	8·4 8·7	·300	W.B.
Σ 1647 ...	12 25	79 44	224·2	1·36	2	7·5 7·8	·340	W.B.
Σ 1658 ...	12 30	82 0	356·5	2·60	1	8·0 9·8	·345	W.B.
Σ 1661 ...	12 30	78 3	238·3	2·50	2	8·5 8·5	·340	W.B.
Σ 1663 ...	12 32	68 15	106·0	0·46	1	7·8 8·7	·315	L.
			102·0	0·63	3	...	·323	W.B.
Σ 1670 (γ Virginis)	12 36	90 54	149·1	5·78	2	3·0 3·0	·453	B.

Star's Name.	R.A. 1900. h m	N.P.D. 1900. ° ′	Position Angle. °	Distance. ″	No. of Meas.	Mags.		Epoch 1900.	Obs.
Σ 1687 (35 Comae Ber.)	12 48	68 13	82·3	0·99	2	5·0	7·8	·375	L.
OΣ 256 ...	12 51	90 25	77·4	0·57	1	7·2	7·6	·460	B.
β 112 ...	12 57	71 5	294·0	2·03	1	6·5	8·5	·435	L.
Σ 1711 ...	12 58	75 59	342·6	0·87	1	8·5	9·0	·345	W.B.
			347·1	0·95	1	...		·435	L.
*	13 2	62 31	198·9	0·48	1	9·0	9·5	·345	W.B.
OΣ 260 ...	13 3	62 31	114·7	0·55	1	7·9	8·3	·345	W.B.
			124·5	0·55	2	...		·359	L.
β 929 ...	12 59	93 7	223·6	0·54	2	6·2	6·2	·444	B.
Σ 1728 (42 Comae Ber.)	13 5	71 57	208·8	0·19	1	6·0	6·0	·345	W.B.
			196·4	0·24	2	...		·419	L.
			205·0	0·33	2	...		·444	B.
OΣ 261 ...	13 7	57 22	344·9	1·51	1	7·0	7·5	·435	L.
			345·8	1·54	1	...		·528	B.
Σ 1734 ...	13 15	86 30	195·0	1·04	1	7·2	7·9	·460	B.
Ho. 260 ...	13 19	60 15	323·2	0·52	1	8·3	8·5	·334	W.B.
			318·6	0·77	2	...		·419	L.
OΣ 266 ...	13 23	73 41	334·1	1·48	1	7·3	7·8	·334	W.B.
OΣ 269 ...	13 28	54 34	218·5	0·30	1	6·5	7·0	·435	L.
			204·2	0·34	2	...		·478	B.
Σ 1768 (25 Canum Ven.)	13 23	53 10	134·2	0·94	1	5·7	7·6	·435	L.
			129·7	0·88	2	...		·646	B.
β 612 ...	13 34	78 45	227·3	0·31	1	6·3	6·5	·427	B.
Σ 1785 ...	13 45	62 30	276·0	1·38	2	7·2	7·5	·438	W.B.
Σ 1808 ...	14 5	62 54	74·5	2·90	2	8·0	9·0	·382	W.B.
OΣ 278 ...	14 8	45 21	80·3	0·29	2	7·5	7·5	·494	B.
			93·8	0·32	2	...		·537	W.B.
β 1272 ...	14 14	40 47	135·2	1·62	1	8·4	9·5	·621	L.
β 1273 ...	14 15	41 35	191·8	...	1	8·6	10·8	·542	W.B.
			187·6	1·07	1	...		·621	L.
Σ 1863 ...	14 34	...	88·3	0·65	3	7·1	7·4	·548	B.
Σ 1865 ... (ζ Boötis)	14 36	75 49	148·6	0·21	3	3·5	3·9	·426	L.
			143·4	0·31	5	...		·482	B.
Σ 1867 ...	14 36	58 15	17·7	1·06	1	7·7	8·2	·460	B.
			12·4	1·09	2	...		·487	W.B.
Σ 1871 ...	14 38	38 11	293·2	1·92	3	7·0	7·0	·548	B.
Σ 1877 ... (ε Boötis)	14 38	62 29	326·6	2·81	1	3·0	6·3	·465	W.B.

Star's Name.	R.A. 1900.	N.P.D. 1900.	Position Angle.	Distance.	No. of Meas.	Mags.		Epoch 1900.	Obs.
	h m	° ′	°	″					
OΣ 285 ...	14 42	47 11	124·5	0·26	2	7·1	7·6	·453	B.
			130·3	0·34	...	...		·520	W.B.
Σ 1883 ...	14 44	83 38	242·2	0·57	1	7·0	7·0	·460	B.
Σ 1888 ... (ξ Boötis)	14 47	70 27	198·2	2·98	1	5·1	7·4	·441	L.
OΣ 287 ...	14 47	44 38	3:8·6	0·77	2	7·5	7·6	·453	B.
			302·8	0·63	2	...		·520	W.B.
β 31 ...	14 48	70 50	189·9	1·44	1	8·4	9·7	·441	L.
OΣ 288 ...	14 49	73 53	189·2	1·70	2	6·5	7·0	·422	L.
			194·2	1·67	1	...		·465	W.B.
Σ 1908 ...	15 1	55 7	145·2	1·30	1	8·2	9·2	·435	L.
			143·4	1·54	2	...		·562	W.B.
Hough 60 ...	15 10	54 44	32·7	0·43	1	8	8	·435	L.
			37·2	0·23	1	...		·446	B.
			46·5	0·24	3	...		·538	W.B.
Σ 1932 ...	15 14	62 48	328·2	0·71	1	5·5	6·0	·430	W.B.
			329·2	0·80	2	...		·437	B.
			332·3	0·66	2	...		·471	L.
Hough 62 ...	15 17	54 40	107·4	1·09	1	8·2	8·3	·435	L.
			292·3	1·20	2	...		·520	W.B.
Σ 1937 ... (η Cor. Bor.)	15 19	59 21	6·0	0·68	2	5·0	5·7	·419	L.
			1·3	0·63	3	...		·426	B.
Σ 1938 ...	15 20	52 16	71·6	0·94	1	4·0	6·7	·575	W.B.
			69·3	0·86	2	...		·589	B.
OΣ 296 ...	15 22	45 38	305·1	1·50	2	7·0	8·6	·676	L.
*	15 25	43 27	340·4	2·88	1	7·5	9·0	·715	L.
Σ 1957 ...	15 31	76 42	153·1	1·07	1	8·0	9·5	·430	W.B.
OΣ 298 ...	15 32	49 50	180·6	1·03	3	7·0	7·3	·658	L.
			179·4	0·94	2	...		·689	B.
Σ 1967 ... (γ Cor. Bor.)	15 39	63 23	116·1	0·48	3	4·0	7·0	·426	B.
			117·1	0·44	1	...		·501	L.
β 619 ...	15 39	76 1	7·9	0·48	3	6·5	7·0	·393	B.
β 621 ...	15 41	44 58	55·5	0·63	1	7·5	8·0	·629	L.
			64·4	0·42	1	...		·657	B.
β 810 ...	15 48	47 14	89·0	1·08	1	8·6	11·2	·637	L.
OΣ 303 ...	15 56	76 27	148·8	0·83	2	7·4	7·9	·427	B.
			142·4	0·65	1	...		·430	W.B.
β 355 ...	16 5	44 21	280·7	0·41	2	7·9	9·2	·668	B.

Star's Name.	R.A. 1900.	N.P.D. 1900.	Position Angle.	Distance.	No. of Meas.	Mags.		Epoch 1900.	Obs.
	h m	° ′	°	″					
Σ 2032	16 2	55 54	210·3	4·36	1	5·0	6·1	·715	L.
β 951	16 20	56 23	51·9	0·85	2	8·2	8·7	·668	B.
Σ 2054	16 23	28 4	355·3	1·07	2	5·7	6·9	·668	B.
Σ 2052	16 25	71 28	91·9	1·93	1	7·5	7·5	·430	W.B.
			93·3	1·86	1	...		·446	B.
			93·2	1·86	1	...		·501	L.
β 813	16 24	63 15	168·7	1·04	2	8·5	8·5	·367	B.
			167·6	0·98	1	...		·430	W.B.
β 814	16 24	49 53	316·5	0·32	2	8·4	8·7	·668	B.
β 817	16 28	66 33	149·7	0·96	2	8·2	8·2	·367	B.
			145·9	1·09	1	...		·501	L.
β 818	16 30	59 17	34·7	3·87	1	6·3	13·5	·643	L.
Σ 2084 (ζ Herculis)	16 38	58 13	239·5	0·80	6	3·0	6·5	·603	L.
			232·1	0·63	2	...		·685	B.
			224·1	0·95	1	...		·993	L.
* ...	16 38	45 20	121·6	5·68	1	9	11	·640	L.
Σ 2091	16 39	48 37	305·7	1·07	3	7·5	8·0	·580	B.
De. 15	16 40	46 20	315·2	0·51	3	8·0	8·5	·580	B.
Σ 2106	16 46	80 25	310·0	0·27	1	6·7	8·4	·548	W.B.
Σ 2107	16 48	61 10	312·4	0·35	1	6·5	8·0	·543	W.B.
			324·3	0·20	2	...		·630	L.
			319·7	0·31	2	...		·668	B.
β 821	16 48	57 59	318·2	1·15	1	8·4	8·9	·405	B.
			311·4	1·29	2	...		·492	L.
Σ 2118	16 57	24 50	93·2	0·16	1	6·4	6·9	·731	B.
Σ 3127	17 11	65 3	192·6	14·63	1	3·0	8·1	·660	L.
OΣ 327	17 12	33 45	313·0	0·17	1	7·6	8·0	·731	B.
β 629	17 15	57 50	344·0	0·99	2	8·4	8·8	·572	L.
β 45	17 15	57 26	290·4	4·97	2	8·6	8·8	·512	L.
β 628	17 16	57 14	355·8	0·50	3	8·8	9·4	·596	L.
* ...	17 16	57 27	28·3	5·55	1	9·5	10·0	·523	L.
* ...	17 16	57 25	302·1	3·23	2	9·0	9·5	·512	L.
β 630	17 17	57 36	224·1	1·39	2	8·6	10·2	·572	L.
β 1250	17 21	59 9	66·2	2·27	1	9·4	9·5	·523	L.
Σ 2173	17 25	90 56	329·5	1·01	3	5·8	6·3	·653	B.
β 1121	17 33	77 24	239·0	0·66	1	8·5	9·0	·523	L.
β 631	17 35	90 36	67·1	0·36	2	7·5	7·6	·641	B.
Σ 2199	17 37	34 12	88·8	1·71	1	7·2	7·8	·630	L.

Star's Name.	R.A. 1900.	N.P.D. 1900.	Position Angle.	Distance.	No. of Meas.	Mags.	Epoch 1900.	Obs.
	h m	° ′	°	″				
β 1251 ...	17 37	74 0	76·7	1·13	2	6·0 11·5	·570	L.
Σ 2203 ...	17 38	48 18	324·0	0·65	1	7·5 7·8	·630	L.
			317·4	0·68	2	...	·798	B.
Σ 2205 ...	17 41	72 15	305·7	1·97	3	8·3 8·6	·600	L.
Σ 2215 ...	17 42	72 16	297·2	0·63	2	5·9 7·9	·581	L.
			295·2	0·67	1	...	·731	B.
Hough 70 ...	17 42	59 25	108·4	0·30	2	8 8	·798	B.
OΣ 337 ...	17 46	82 44	270·3	0·39	3	7·5 8·0	·653	B.
OΣ 338 ...	17 47	74 39	18·6	0·69	3	6·5 7·0	·652	B.
			15·5	0·75	1	...	·698	L.
*	17 47	74 39	354·5	1·26	1	10·0 10·5	·698	L.
A.C. 8 ...	17 19	60 18	58·4	0·32	1	8·0 9·8	·865	B.
A.C. 9 ...	17 50	60 10	55·4	0·95	1	8·4 8·7	·865	B.
β 1125 ...	17 57	88 40	19·0	1·00	1	5·1 9·1	·671	L.
Σ 2262 ... (τ Ophiuchi)	17 58	98 11	257·7	1·29	1	5·0 5·7	·671	L.
Σ 2272 (70 Ophiuchi)	18 0	87 28	246·9	1·61	9	4·1 6·1	·566	W.B.
OΣ 341 ...	18 1	68 34	77·0	0·26	2	6·4 7·7	·681	B.
OΣ 343 ...	18 2	41 52	87·5	2·61	1	7·2 10·2	·638	L.
Σ 2281 ...	18 4	86 2	224·8	0·31	3	5·7 7·2	·572	W.B.
Σ 2283 ...	18 4	83 52	80·3	1·11	2	7·2 7·7	·537	W.B.
Σ 2289 ...	18 5	73 32	233·6	1·20	3	6·5 7·0	·548	W.B.
Σ 2294 ...	18 9	89 51	100·3	0·19	1	7·4 7·7	·624	B.
β 1091 ...	18 9	51 26	35·3	0·29	2	8·6 8·6	·798	B.
β 641 ...	18 17	68 33	344·1	0·96	2	7·3 9·0	·584	W.B.
			347·0	0·95	2	...	·687	L.
*	18 18	69 26	110·8	6·51	1	10 11	·698	L.
Σ 2315 ...	18 21	62 39	203·9	0·26	2	7·0 8·0	·589	L.
			212·9	0·17	1	...	·543	W.B.
Σ 2318 ...	18 21	64 4	252·8	21·12	1	7·9 10·0	·465	W.B.
β 1203 ...	18 21	89 15	68·0	0·22	1	7·5 7·7	·624	B.
			90·2	0·20	1	...	·676	L.
OΣ 543 ...	18 22	43 11	132·9	1·01	2	8·0 10·0	·688	L.
			128·6	1·11	2	...	·798	B.
OΣ 351 ...	18 23	41 19	18·0	0·52	2	7·0 7·0	·688	L.
			20·8	0·56	2	...	·798	B.
OΣ 354 ...	18 27	83 18	165·2	0·70	2	7 8	·574	W.B.
Hough 86 ...	18 30	54 54	181·7	0·29	1	8 9	·660	L.

Star's Name.		R.A. 1900.	N.P.D. 1900.	Position Angle.	Distance.	No. of Meas.	Mags.		Epoch 1900.	Obs.
		h m	° ′	°	″					
OΣ 357	...	18 31	78 24	242·4	0·33	2	8·2	8·2	·574	W.B.
				234·8	0·47	1	...		·676	L.
OΣ 358	...	18 31	73 12	192·4	1·95	3	6·8	7·2	·513	W.B.
				190·2	1·77	...	...		·676	L.
Hough 87...		18 34	73 34	103·1	0·38	2	7·8	8·1	·574	W.B.
				102·1	0·39	1	...		·676	L.
* ...	...	18 34	61 18	257·7	1·11	2	9·5	10·0	·597	W.B.
				262·0	0·92	1	...		·698	L.
* ...	...	18 22	63 57	309·6	5·56	1	10	10	·698	L.
Σ 2356	...	18 34	61 23	60·4	0·90	3	8·2	8·6	·586	W.B.
				60·8	0·98	1	...		·698	L.
* ...	...	18 35	61 22	30·1	6·27	1	9	9	·698	L.
Σ 2362	...	18 35	54 2	2·6	4·08	1	7·1	8·4	·660	L.
Hough 437 A.D.		18 37	58 27	301·4	0·32	1	8	8	·643	L.
	C.D.	...	...	339·0	4·14	1	...		·643	L.
Σ 2367	...	18 37	59 48	85·7	0·18	2	7·2	7·6	·672	L.
				83·5	0·17	3	...		·740	B.
Σ 2369	...	18 39	87 30	92·5	0·95	1	8	8	·624	B.
Σ 2400	A.B.	18 44	73 51	188·3	1 88	1	8·0	11·1	·709	L.
	A.C.	...	...	178·3	2·92	1	8·0	11·0	·619	W.B.
		...	...	188·6	2·79	1	...		·709	L.
	B.C.	...	...	188·2	0·92	1	11·1	11·0	·709	L.
	A.D.	...	...	157·1	0·39	1	8·0	9·5	·709	L.
Σ 2402	...	18 45	79 25	205·8	0·82	3	8·0	8·4	·626	W.B.
β 971	...	18 45	40 41	8·3	0 27	1	6·5	8·5	·731	B.
β 1255	...	18 52	41 15	89·7	1·43	1	5·8	12·5	·638	L.
β 648	...	18 53	57 16	224·2	1·17	2	6·0	9·2	·622	L.
				228 9	1·10	1	...		·731	B.
Σ 2422	...	18 53	63 54	91·2	0·91	3	7·9	8·2	·587	W.B.
β 649	...	18 55	57 40	12·2	1·43	1	8·2	10·6	·731	B.
Σ 2437	...	18 57	70 59	62·7	0·71	3	7·8	8·2	·640	W.B.
Σ 2454	...	19 2	59 43	252·4	0·96	2	8	9	·674	W.B.
				254·2	0·80	1	...		·731	B.
* ...	...	19 2	60 5	190·1	1·03	1	9	10	·501	L.
Σ 2455	...	19 3	67 59	80·2	3·39	4	7	8	·635	W.B.
Σ 2488	...	19 11	70 9	326·2	1·58	1	8·5	9·7	·772	W.B.
OΣ 368	...	19 11	74 1	217·2	0·74	3	8	9	·644	W.B.
				213·8	0·95	1	...		·671	L.

Star's Name.	R.A. 1900. h m	N.P.D. 1900. ° ′	Position Angle. °	Distance. ″	No. of Meas.	Mags.		Epoch 1900.	Obs.
OΣ 371 ...	19 12	62 42	153·0	0·88	3	7	7	·644	W.B.
β 1256 ...	19 14	83 51	36·5	0·63	1	8·3	8·3	·624	B.
			34·0	0·63	1	...		·671	L.
H.A.H. 95...	19 15	87 14	160·4	0·40	1	6·0	6·5	·624	B.
			149·8	0·28	1	...		·671	L.
β 141 ...	19 18	67 42	77·0	0·72	1	7·5	8·5	·676	B.
β 1129 ...	19 19	37 50	329·1	0·28	1	6·3	6·3	·865	B.
Σ 2525 ...	19 22	62 52	321·7	0·47	2	8·0	8·0	·619	B.
OΣ 375 ...	19 30	72 7	150·4	0·57	2	8·0	9·0	·619	B.
			149·0	0·28	1	...		·772	W.B.
Σ 2544 ...	19 32	81 56	202·9	1·00	1	7·8	9·5	·671	L.
Σ 2556 ...	19 35	68 0	145·7	0·45	2	7·3	7·8	·619	B.
β 1132 ...	19 39	63 18	211·3	0·53	1	8·3	8·7	·624	B.
*	19 40	63 6	349·4	0·33	1	...		·624	B.
β 658 ...	19 40	62 9	297·6	0·50	2	6·7	9·7	·619	B.
Σ 2579 ... (δ Cygni)	19 42	45 7	300·4	1·44	2	3·0	7·9	·619	B.
A.G.C. 11 ...	19 44	71 7	162·9	0·20	2	4·5	6·0	·619	B.
OΣ 387 ...	19 45	54 58	334·1	0·57	1	7·2	8·2	·778	B.
Hough 580	19 48	67 48	271·7	0·78	2	8·0	8·1	·696	B.
			279·7	0·54	1	...		·772	W.B.
Σ 2600 ...	19 51	67 46	58·3	3·20	2	8·3	9·7	·710	W.B.
			54·8	3·06	1	...		·756	B.
β 425 A.B.	19 53	69 59	238·6	1·43	1	8·4	8·5	·756	B.
			242·6	1·41	1	...		·772	W.B.
A.C.			41·8	20·22	1		11·9	·772	W.B.
A.C. 16 ...	19 54	63 2	56·1	0·44	2	7	9	·696	B.
			56·6	0·37	1	...		·660	L.
			54·0	0·49	1	...		·772	W.B.
Σ 2607 A.C.	19 55	48 0	291·8	3·24	1	7·2	9·2	·778	B.
OΣ 392 A.B.			300·7	0·28	1	7·2	9·0	·778	B.
OΣ 395 ...	19 58	65 21	275·8	0·66	1	5·8	6·2	·709	L.
			103·8	0·55	2	...		·739	B.
*	19 59	65 22	20·1	0·45	1	8	9	·709	L.
Σ 2624 A.B.	19 0	54 16	173·6	1·56	1	7·2	7·8	·719	W.B.
β 57 ...	20 1	74 47	119·7	2·38	1	6·7	11·3	·671	L.
Hough 128	20 20	47 20	26·0	1·02	1	6·3	10·9	·660	L.
*	20 20	47 11	176·0	1·55	1	8	9	·660	L.

Star's Name.	R.A. 1900. h m	N.P.D. 1900. ° ′	Position Angle. °	Distance. ″	No. of Meas.	Mags.		Epoch 1900.	Obs.
Σ 2695 ...	20 28	64 39	80·6	1·04	3	6·2	8·0	·630	W.B.
β 670 ...	20 28	76 24	45·1	0·39	1	8·5	8·9	·671	L.
*	20 28	76 24	143·0	0·31	1	9·0	9·5	·671	L.
β 151 (β Delphini)	20 33	75 45	9·0	0·64	1	4·5	6·0	·613	B.
			9·8	0·63	1	...		·671	L.
Hough 152...	21 8	62 7	329·6	0·53	1	8·5	9·5	·616	L.
			319·5	0·52	3	...		·819	W.B.
OΣ 535 ...	21 10	80 27	206·0	0·33	1	4·1	4·1	·613	B.
Σ 2799 ...	21 24	79 21	295·3	1·41	3	6·6	6·6	·612	W.B.
Σ 2804 ...	21 28	69 44	332·1	3·11	3	7·3	8·0	·612	W.B.
β 1212 ...	21 34	90 33	261·8	0·51	1	6·5	6·9	·613	B.
Hough 165...	21 38	71 29	76·5	0·35	2	8·0	8·2	·794	W.B.
Σ 2822 ...	21 39	61 43	126·6	2·66	1	4·0	5·0	·019	L.
			123·4	2·59	3	...		·790	W.B.
Hough 166...	21 40	62 38	86·9	0·24	1	7·5	7·5	·613	B.
			92·4	0·29	2	...		·655	L.
			93·2	0·31	1	...		·739	W.B.
Σ 2824 (κ Pegasi A.C.)	21 40	64 49	295·7	12·77	1	3·9	10·8	·537	W.B.
β 989 (κ Pegasi A.B.)	21 40	64 49	259·2	0·14	5	3·9	5·0	·555	L.
			251·2	0·14	4	...		·689	W.B.
			253·3	0·16	1	...		·613	B.
*	21 41	64 55	295·3	4·36	1	9·5	10·0	·694	L.
Hough 171...	21 48	62 41	170·6	0·68	1	8	8	·613	B.
			169·4	0·76	2	...		·655	L.
			159·7	0·81	1	...		·904	W.B.
β 75 ...	21 50	79 35	43·3	0·95	1	8·1	8·3	·756	B.
			46·7	0·89	1	...		·816	W.B.
Σ 2849 ...	21 53	76 19	266·8	1·43	1	8·2	10·7	·694	L.
			265·6	1·53	2	...		·767	W.B.
Hough 179	22 8	60 26	257·3	0·57	2	8·0	8·5	·655	L.
			259·4	0·52	1	...		·756	B.
			260·1	0·41	1	...		·958	W.B.
Σ 2881 ...	22 10	60 57	93·8	1·47	1	7·7	8·2	·616	L.
			98·5	1·33	3	...		·714	W.B.
Hough 180	22 12	46 38	221·2	0·55	1	7·0	7·5	·931	B.
β 1216 ...	22 15	61 0	318·1	0·53	1	8·4	8·7	·694	L.
			310·0	0·49	1	...		·756	B.
			315·4	0·68	2	...		·944	W.B.

Star's Name.	R.A. 1900.	N.P.D. 1900.	Position Angle.	Distance.	No. of Meas.	Mags.	Epoch 1900.	Obs.
	h m	° ′	°	″				
Σ 2900 ...	22 19	69 40	176·6	1·54	1	6·0 9·2	·717	W.B.
β 1218 ...	22 23	60 50	52·5	1·42	2	8·6 8·8	·811	W.B.
			53·6	1·45	1	...	·756	B.
Hough 296	22 36	75 59	57·3	0·32	2	5·5 5·5	·898	B.
Σ 2934 ...	22 37	69 6	143·8	0·83	1	8·2 9·2	·694	L.
			138·3	0·85	3	...	·838	W.B.
β 1144 ...	22 38	60 18	83·5	0·28	1	9·5 9·5	·790	L.
β 710 ...	22 38	60 50	235·5	0·36	1	8·0 8·5	·790	L.
β 711 ...	22 40	79 20	47·9	1·07	1	9·0 10·2	·790	L.
OΣ 483 ...	22 54	78 48	221·9	0·81	2	6·0 7·5	·743	W.B.
			228·6	0·94	1	...	·756	B.
β 1025 ...	23 9	77 53	277·2	0·58	1	8·0 10·8	·739	W.B.
β 79 ...	23 12	92 5	85·4	0·70	1	8·0 8·5	·931	B.
β 80 ...	23 14	85 10	10·7	0·27	1	8·0 8·5	·931	B.
β 720 ...	23 29	59 14	168·7	0·39	1	5·5 5·5	·790	L.
			159·3	0·31	1	...	·964	B.
			168·3	0·34	1	...	·983	W.B.
β 858 ...	23 36	58 0	266·0	0·56	2	8·0 8·2	·948	B.
			266·4	0·58	1	...	·983	W.B.
Σ 3050 ...	23 54	56 51	213·8	2·40	1	6·0 6·0	·816	W.B.
Σ 3056 ...	23 59	56 20	147·8	0·52	2	7·4 7·4	·477	B.
			143·0	0·52	1	...	·958	W.B.

Results of Double-star Measures with the 8-inch Equatorial at Windsor, New South Wales, in the Years 1899 *and* 1900. By John Tebbutt.

Ref. No.	Star.	Observed Mags.	Approx. Place of Star at Beginning of Year. R.A. h m	Dec. S. ° ′	Time of Obs. 1899+	Position Angle. °	Distance. ″	No. of Obs.	Mag. power.	Eyes.	Hour-angles h m	h m	Weight 1 to 5.
1	λ Toucani	7, 8	0 48·6	70 3	1·071	81·1	21·00	10–6	138	R	4 45 W	5 13 W	3
2	ζ Phœnicis	4½, 8	1 4·2	55 47	1·156	243·5	6·72	10–6	138	R	4 23 W	4 46 W	3
3	P.I. 127	6, 8	1 31·5	30 25	1·060	94·4	2·02	10–7	230	R	2 43 W	3 11 W	3
4	,,	6, 8	,,	,,	1·068	92·4	2·22	10–7	230	R	3 2 W	3 31 W	4
5	,,	...	,,	,,	1·071	93·6	2·09	10–6	230	R	3 18 W	3 42 W	3
6	p Eridani	...	1 36·0	56 42	1·047	223·0	8·33	10–8	230	R	2 18 W	2 58 W	3
7	,,	...	,,	,,	1·049	222·3	7·81	10–6	230	R	1 41 W	2 22 W	3
8	,,	...	,,	,,	1·060	223·7	8·22	10–7	230	R	1 40 W	2 20 W	2
9	θ Eridani	5, 6	2 54·5	40 42	1·140	87·3	8·09	6–5	230	R	3 39 W	4 2 W	2
10	,,	4½, 5½	,,	,,	1·145	87·7	8·47	10–6	230	R	...	2 55 W	3
11	h 3556	7, 9	3 8·9	44 48	1·077	219·7	2·52	10–5	138	P	2 37 W	3 21 W	3
12	,,	...	,,	,,	1·085	215·5	1·89	10–3	230	R	2 53 W	3 34 W	3
13	,,	6½, 9	,,	,,	1·085	219·1	2·63	10–3	138	P	2 53 W	3 34 W	4
14	h 3586$_3$	6½, 7	3 36·1	60 6	1·156	270·8	57·43	10–4	138	R	2 39 W	3 7 W	3
15	h 3586$_2$	7½, 8	3 36·2	40 41	1 145	326·9	7·75	10–6	230	P	3 13 W	...	4

Ref No.	Star.	Observed Mags.	Approx. Place of Star at Beginning of Year. R.A.	Dec. S.	Time of Obs.	Position Angle.	Distance.	No. of Obs.	Mag. power.	Eyes.	Hour-angles.		Weight 1 to 5.
			h m	° ′	1899+	°	″				h m	h m	
16	*h* 3586_2	7½, 8	3 36·2	40 41	1·151	327·3	7·68	10-6	138	P	3 20 W	3 57 W	4
17	*f* Eridani	6, 6½	3 44·9	37 56	1·151	207·6	7·46	10–6	138	P	4 0 W	4 19 W	3
18	„	7½, 8	„	„	1·153	208·2	7·23	7–5	138	R	1 44 W	2 14 W	4
19	θ Reticuli	7, 8	4 16·6	63 30	1·156	2·4	3·93	10–6	138	P	2 37 W	3 4 W	4
20	ι Pictoris	6, 6½	4 48·7	53 38	1·175	57·8	12·15	10–5	138	R	3 14 W	3 37 W	3
21	„	6, 6½	„	„	1·184	58·0	11·70	10–5	138	R	1 23 W	1 50 W	3
22	*h* 3823	8, 8	5 56·6	31 3	1·233	112·0	2·83	10–6	300	R	3 43 W	4 12 W	4
23	„	...	„	„	1·236	112·7	2·60	10–6	300	R	3 22 W	3 52 W	3
24	„	8, 8	„	„	1·299	115·2	2·69	10–8	138	R	2 59 W	3 32 W	3
25	Lacaille 2145	...	6 2·2	48 27	1·156	42·2	...	10	300	R	1 30 W	1 45 W	2
26	„	7, 7	„	„	1·175	41·8	...	10	300	R	1 6 W	1 35 W	3
27	„	7, 7	„	„	1·225	38·8	1·77	10–8	300	P	3 19 W	3 47 W	4
28	„	...	„	„	1·227	38·8	1·42	7–5	300	P	3 51 W	4 23 W	2
29	„	...	„	„	1·233	39·8	1·93	10–7	300	R	2 22 W	2 57 W	4
30	„	...	„	„	1·233	39·2	1·96	10–6	300	P	2 57 W	3 22 W	5
31	γ Argûs A.B.	2, 3½	8 6·5	47 2	1·101	219·9	40·09	10–5	138	R	1 58 E	1 9 E	3
32	„	2, 3½	„	„	1·112	219·6	41·23	10–5	138	P	3 24 E	2 55 E	3
33	γ Argûs A.C.	2, 7	„	„	1·112	151·4	62·05	7–4	...	P	2 21 E	1 46 E	3

Ref. No.	Star.	Observed Mags.	Approx. Place of Star at Beginning of Year. R.A.	Dec. S.	Time of Obs.	Position Angle.	Distance.	No. of Obs.	Mag. power.	Eyes.	Hour-angles.		Weight 1 to 5.
			h m	° ′	1899+	°	″				h m	h m	
34	γ Argûs A.C.	2½, 8	8 6·5	47 2	1·126	151·8	62·08	10–5	138	P	2 23 E	1 49 E	3
35	α Crucis	...	12 21·0	62 33	1·400	117·6	4·90	10–10	300	P	4 50 E	4 28 E	4
36	,,	...	,,	,,	1·414	119·9	5·16	10–8	300	R	2 33 E	2 9 E	4
37	γ Centauri	...	12 36·0	48 24	0·332	356·5	1·60	10–10	300	P	2 14 E	1 43 E	4
38	,,	...	,,	,,	0·334	357·2	1·60	10–8	300	P	1 58 E	1 32 E	3
39	,,	4, 4	12 36·0	48 25	1·299	357·6	1·84	10–10	300	P	2 28 E	2 2 E	4
40	,,	...	,,	,,	1·301	358·6	1·84	10–10	300	P	3 35 E	3 8 E	4
41	,,	4, 4	,,	,,	1·301	358·5	1·77	10–8	300	P	3 8 E	2 49 E	5
42	,,	4, 4	,,	,,	1·304	356·2	1·57	10–7	535	P	1 56 E	1 30 E	5
43	,,	4, 4	,,	,,	1·310	358·2	1·51	10–8	535	P	3 41 E	3 17 E	5
44	,,	4, 4	,,	,,	1·329	356·8	1·48	10–7	535	P	2 38 E	2 14 E	4
45	γ Virginis	...	12 36·6	0 54	1·400	150·3	5·95	10–8	300	P	3 19 E	2 56 E	3
46	,,	...	,,	,,	1·414	151·1	6·09	10–8	300	R	1 12 E	0 41 E	5
47	,,	...	,,	,,	1·416	151·4	5·97	10–8	535	R	1 10 E	0 45 E	5
48	,,	...	,,	,,	1·422	148·8	6·00	10–10	535	P	2 58 E	2 29 E	4
49	β Muscæ	4, 4	12 40·1	67 34	1·301	341·9	1·42	10–10	300	R	2 33 E	1 51 E	5
50	,,	4, 4	,,	,,	1·304	342·8	1·08	10–10	535	P	2 54 E	2 15 E	5
51	,,	4, 4	,,	,,	1·329	343·1	...	10	535	R	2 7 E	1 39 E	3

Ref. No.	Star.	Observed Mags.	Approx. Place of Star at Beginning of Year. R.A.	Dec. S.	Time of Obs.	Position Angle.	Distance.	No. of Obs.	Mag. power.	Eyes.	Hour-angles.		Weight 1 to 5.
			h m	° ′	1899+	°	″				h m	h m	
52	β Muscæ	...	12 40·1	67 34	1·332	341·0	1·30	10–8	300	P	2 51 E	2 9 E	3
53	„	...	„	„	1·332	343·0	...	10	535	P	2 51 E	2 9 E	4
54	„	4½, 4½	„	„	1·419	339·2	...	10	300	R	0 30 E	0 5 E	3
55	*h* 4634	8, 9	13 51·5	55 29	1·332	26·3	14·35	10–6	138	P	2 59 E	2 28 E	5
56	„	...	„	„	1·334	26·2	14·31	10–10	138	P	4 25 E	3 57 E	5
57	Arg. G. Cat. 19385	8, 8	14 14·5	41 59	1·425	215·3	1·98	10–5	138	R	1 51 E	1 16 E	3
58	α Centauri	...	14 32·7	60 25	0·323	209·0	21·74	10–10	300	P	4 23 E	3 36 E	3
59	„	...	„	„	0·332	210·6	21·99	10–10	300	R	5 6 E	4 34 E	2
60	„	...	„	„	0·334	209·7	21·90	10–6	300	P	3 21 E	2 54 E	3
61	„	...	„	„	0·337	209·5	22·14	10–8	300	P	3 29 E	3 0 E	3
62	„	...	„	„	0·340	209·8	22·21	10–10	300	P	2 56 E	2 27 E	3
63	„	...	14 32·8	60 25	1·301	210·7	21·87	10–10	300	P	3 32 E	2 57 E	3
64	„	...	„	„	1·304	210·8	...	10	535	R	5 38 E	4 57 E	4
65	„	...	„	„	1·304	210·7	22·06	10–8	535	P			4
66	„	...	„	„	1·334	209·9	21·79	10–10	535	P	4 8 E	3 39 E	5
67	„	...	„	„	1·356	210·8	21·90	10–7	535	P	2 45 E	2 14 E	3
68	„	...	„	„	1·384	210·2	22·44	10–6	300	P	3 51 E	3 25 E	3
69	π Lupi	5, 5	14 58·3	46 40	1·416	88·1	1·17	10–8	300	R	2 54 E	2 26 E	5

Ref. No.	Star.	Observed Mags.	Approx. Place of Star at Beginning of Year. R.A.	Dec. S.	Time of Obs.	Position Angle.	Distance.	No. of Obs.	Mag. power.	Eyes.	Hour-angles.		Weight 1 to 5.
			h m	° ′	1899+	°	″				h m	h m	
70	π Lupi	...	14 58·3	46 40	1·419	86·2	...	10	300	R	2 10 E	1 47 E	3
71	”	...	”	”	1·422	86·2	1·57	10–5	300	R	0 30 E	0 8 E	5
72	”	...	”	”	1·425	85·9	1·78	10–7	300	R	1 50 E	1 26 E	4
73	Antares	1, 7½	16 23·3	26 13	1·400	276·9	3·44	10–8	300	R	2 36 E	1 57 E	4
74	”	1, 7½	”	”	1·422	275·1	3·33	10–10	300	R	2 29 E	2 4 E	4
75	”	1, 8	”	”	1·425	275·7	3·23	10–8	300	R	2 41 E	2 18 E	4
76	β 416	6½, 8	17 12·1	34 53	1·416	300·1	1·42	10–6	300	P	4 25 E	3 58 E	4
77	”	6½, 8	”	”	1·422	298·7	2·07	10–7	300	P	2 14 E	1 49 E	4
78	”	6½, 7½	”	”	1·425	298·2	2·36	10–8	300	R	3 0 E	2 32 E	4
79	γ Coronæ Aust.	6, 6	18 59·7	37 12	1·400	143·3	1·93	10–8	300	P	4 18 E	3 53 E	3

Remarks.

In the column headed "Eyes" P denotes that the line joining the observer's eyes was parallel to that joining the components, and R that those lines were at right angles. The column headed "Hour-angles" gives the hour-angles between which the measures were made, and that headed "Weight" the value of each result on a scale of 1 to 5, 1 denoting the worst possible, and 5 the best possible, conditions. 2, companion dull blue. 8, observations in twilight. 11, 12, 13, measures difficult, owing to inequality of components; companion faint and bluish. 22, 23, 24, 35, 36, 39, 41, 42, 43, 44, 45, 46, 47, 49, 50, 51, 57, 69, 71, 72, 79, components noted equal. 26, 27, the preceding or south component evidently the brighter. 35, measures in full daylight. 36, measures in twilight. 37, the north component probably the brighter. 48, measures in sunlight and twilight. 55, 56, principal star white and companion blue. 73, 74, 75, principal star orange and companion pale blue.

The Peninsula, Windsor, N.S. Wales:
1901 *March* 25.

Errata.

Vol. LXI., page 342, *for* $+43^\circ\ 33'\ 39''\cdot51$, *read* $+43^\circ\ 33'\ 42''\cdot51$.

" " 344, Star 59, *for* 7·4506, *read* 7·4454.

" " 347, Star 155, *for* 3·9712. *read* 3·9612.

// MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

VOL. LXI. JUNE 14, 1901. No. 8

E. B. KNOBEL, Esq., Vice-President, in the Chair.

Francis William Crook, B.A., Barrister-at-Law, 4 Overcliff, Gravesend, Kent;
Frank Lowman, B.A., Lecturer in Science, St. John's College, Battersea, S.W.; and
Charles Nielsen, 15 Cliff Terrace, Hartlepool,

were balloted for and duly elected Fellows of the Society.

The following candidate was proposed for election as a Fellow of the Society, the name of the proposer from personal knowledge being appended:—

William John Greenstreet, M.A. (Cantab.), Head Master, Marling School, Stroud, Gloucestershire (proposed by Charles T. Whitmell).

Seventy-one presents were announced as having been received since the last meeting, including, amongst others:—

Rev. S. B. Burnaby, Elements of the Jewish and Muhammadan Calendars, presented by the author; W. de Sitter, Discussion of heliometer observations of *Jupiter's* satellites made by Sir D. Gill and W. H. Finlay, presented by the author; Taylor's General Catalogue of Stars for 1835·0, revised and edited by A. M. W. Downing, presented by the editor; *Astronomischer Jahresbericht*, Band 2, 1900, herausgegeben von

W. F. Wislicenus, presented by the editor; *Monthly Notices of the Royal Astronomical Society*, vol. 27, presented by W. C. Johnson; Photographs of the great Comet, 1901, presented by Sir David Gill.

The Great Comet of 1901, *as observed at the Royal Observatory, Cape of Good Hope.* By Sir David Gill, K.C.B., F.R.S., His Majesty's Astronomer at the Cape.

On April 24, at 2^h 54^m P.M., a telegram was received as follows:—

From Arthur Hill, Queenstown.

Royal Observatory, Cape Town:

"Saw a Comet this morning at 5 o'clock due East."

The following morning (April 24, astronomical time), the comet was seen by Mr. Innes, Mr. Lunt, and myself. Its position was first observed by Mr. Innes with the 10-inch guiding telescope of the astrographic equatorial, and afterwards by Messrs. Lunt and Innes with the 18-inch refractor of the McClean telescope. The nucleus was visible for some time after sunrise, but could not be followed as far as meridian passage. The observed places on this date depend on readings of the R.A. and Decl. circles, of which the index-errors were found by observations of the planet *Mercury*. The places given are corrected for refraction. On April 25 (astronomical date) there was dense fog on the eastern horizon, and the comet could not be seen. On April 26 similar circle observations to those of April 24 were secured with great difficulty by Messrs. Innes and Lunt on account of the strong light of the background of the sky.

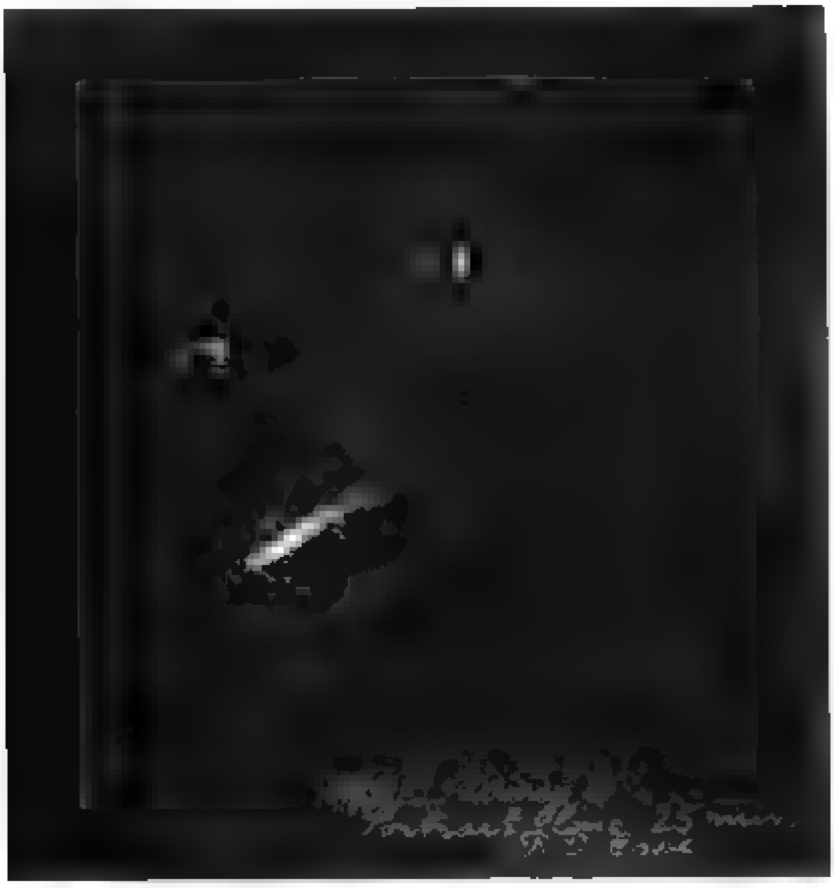
On April 27 Mr. Lunt pointed the 6-inch equatorial to the ridge of the distant Hottentot Hollands Mountains at the expected setting in declination, and so saw the comet enter the field over the mountains, and thus obtained some readings of the circles, but the results are of doubtful value.

Cloudy weather intervened from April 27 till May 3, when the first accurate series of observations was secured by Mr. Innes, and no subsequent opportunity was lost by him. The preliminary results of reduction of all his observations are attached, together with an approximate orbit derived by him from his observations of May 3, 5 and 7.

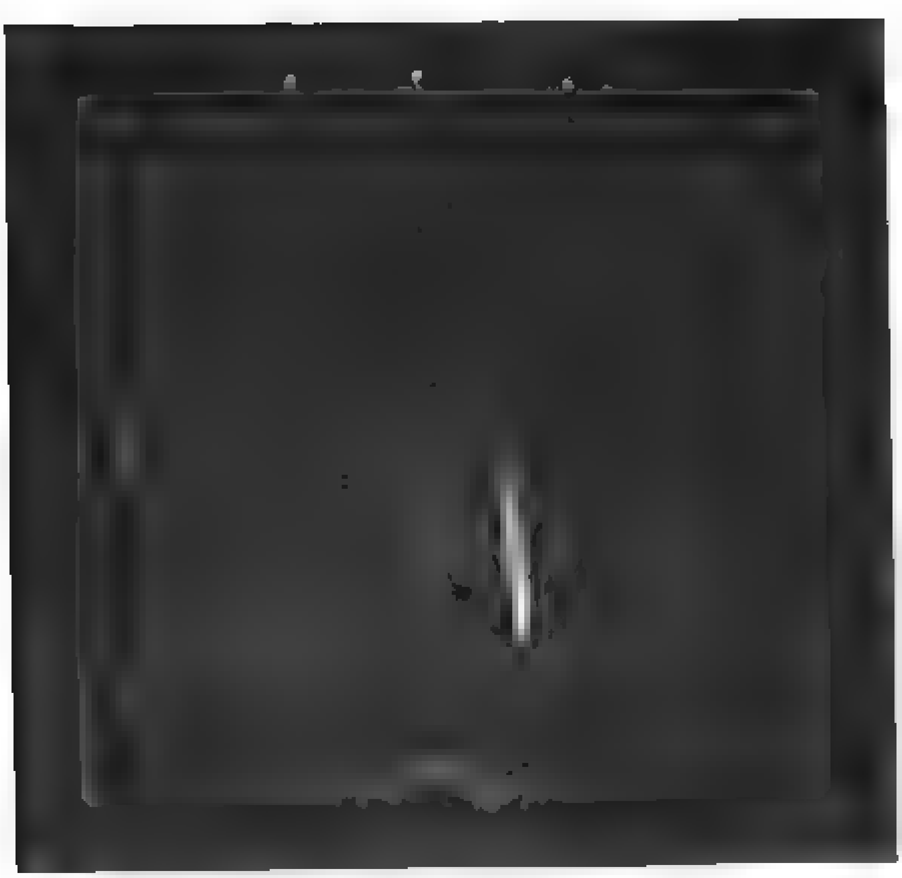
Mr. Innes's drawing represents the comet as seen with the naked eye on April 24, the formation of the head and of the portions of the tail near the head being drawn with the assistance of the telescope.

1901 May 4
McCLEAN TELESCOPE
Exposure 15 minutes

1901 May 5
13 IN. ASTROGRAPHIC EQUATORIAL



1901 May 6
PORTRAIT LENS
Exposure 25 minutes



1901 May 7
PORTRAIT LENS
Exposure 25 minutes

Mr. Lunt's drawing of the comet on May 12 gives a very exact representation of the naked-eye view of this remarkable object.

It is desirable to defer a more detailed account of the physical appearance of the comet until our photographs, &c., have been properly reproduced and discussed.

Meanwhile the accompanying photographs and the notes of Mr. Lunt and Mr. Innes will be of interest to the Society.

Lantern Slides prepared from Negatives taken with the McClean Telescope.

*1. Taken 1901 May 4. Exposure 15^m.
2. „ „ 6. „ 10^m.

Lantern Slides prepared from Negatives taken with a Portrait Lens.

*3. Taken 1901 May 6. Exposure 25^m.
*4. „ „ 7. „ 25^m.
5. Copy of Mr. Lunt's drawing of comet on May 12.

Contact Prints from Original Negatives taken with the 13-inch Astrographic Equatorial.

No. 6300*a*.	May 4.	Exposure,	10^s at	$9^h\ 14^m$	sid. time.
6300*b*.	„ 4.	„	20^s	$9^h\ 19^m$	„
*6302.	„ 5.	„	$13^m\ 44^s$	$9^h\ 15^m$	„
6305.	„ 6.	„	15^m	$9^h\ 28^m$	„

The spectrum of the comet appears to be continuous; at least, with the means at our disposal, we have been unable to detect any bright lines. It unfortunately happened that, only a few days before the comet appeared, the large McClean spectroscope was sent off to England in order to have a new prism-box fitted.

Circle Readings.†

1901.	G.M.T.	R.A.	Dec.	
	h m	h. m s	° ′	
April 24	16 37·2	1 29 55	+3 27·8	Innes, 10-inch telescope
	17 5·0	1 29 56·1	3 26 9	Lunt, McClean „
	17 31·4	1 30 14·5	...	„ „ „
	17 34·4	...	3 25·4	„ „ „
26	16 54·0	1 58 8·4	1 17·9	Innes, 10-inch telescope
	17 11·6	1 58 8·6	1 19·0	Lunt, McClean telescope
27	17 10·8	2 14 6·2	+0 24·8	Lunt, 6-inch telescope

* Reproduced. Plates 14 and 15.
† All corrected for refraction.

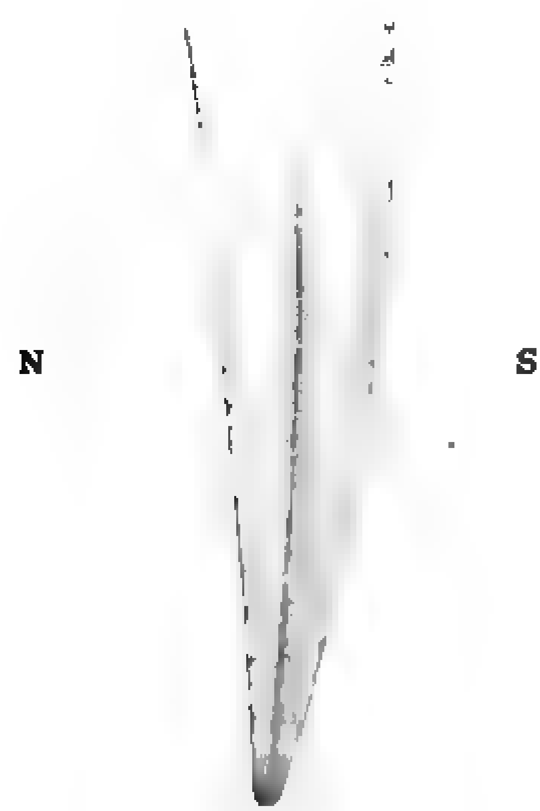
*Equatorial Comparisons.**

1901.		G.M.T. h m s	R.A. h m s	Dec. ° ′ ″	
May	3	5 4 43	3 40 32·39	−0 32 18·6	Innes, McClean telescope
	4	5 15 0	3 54 29·23	−0 18 27·9	Innes, 7-inch telescope
	5	4 57 46	4 7 9·97	−0 1 32·4	" " "
		5 29 24	4 7 25·23	−0 1 7·7	" " "
	6	4 49 45	4 19 7·04	+0 18 23·3	" " "
		5 5 48	4 19 14·91	+0 18 34·8	" " "
		5 15 18	4 19 19·21	+0 18 37·1	" " "
	7	5 1 15	4 30 24·20	+0 40 15·0	" " "
	11	4 50 17	5 7 38·74	+2 13 45·1	" " "
	12	4 49 56	5 15 22·65	+2 36 50·6	" " "
		5 37 58	5 15 38·08	+2 37 39·3	" " "
	13	4 59 28	5 22 38·71	+2 59 39·5	" " "

Orbit.

T 1901 April 24·244
ω 202° 58′
☊ 110° 10′
ι 130° 44′
q 0·24251

Observations used, May 3–5–7.



Drawing by R. T. A. Innes. 1901 April 24.

* All corrected for refraction.

Observations by Mr. R. T. A. Innes.

1901 April 24. On account of conflicting telegrams, I had kept watch from about 15^h. About $17^h\ 30^m$, when day was breaking, I had begun to despair of seeing any comet, but on giving a final look round in very bright twilight I saw two sheafs of light rising above the mountains in the east. A few minutes later the comet had entirely risen. It was a brilliant object with a bright nucleus and a tail about 10° in length, curved on the southern side. The colour of all was a very deep yellow, but the comet was very near the horizon. Through the 10-inch guiding telescope (now in broad daylight) the yellow tint of the nucleus was very marked. There was no coma visible, the tails (see drawing) springing directly from the nucleus. By comparison with *Mercury*, the nucleus was estimated to be two-thirds of *Mercury's* diameter, which makes it about 4″; its brightness was about equal to *Mercury's*.

When next seen with the 10-inch on April 26 the comet was very faint, but the nucleus did not seem smaller. On April 27 I could not find the comet, nor did I see it again until the evening of May 3, when the tail was quite altered. It now consisted of two nearly equal portions streaming from each side of the nucleus, not very unlike De La Rue's drawings of the comet of 1861, but the nucleus was round.

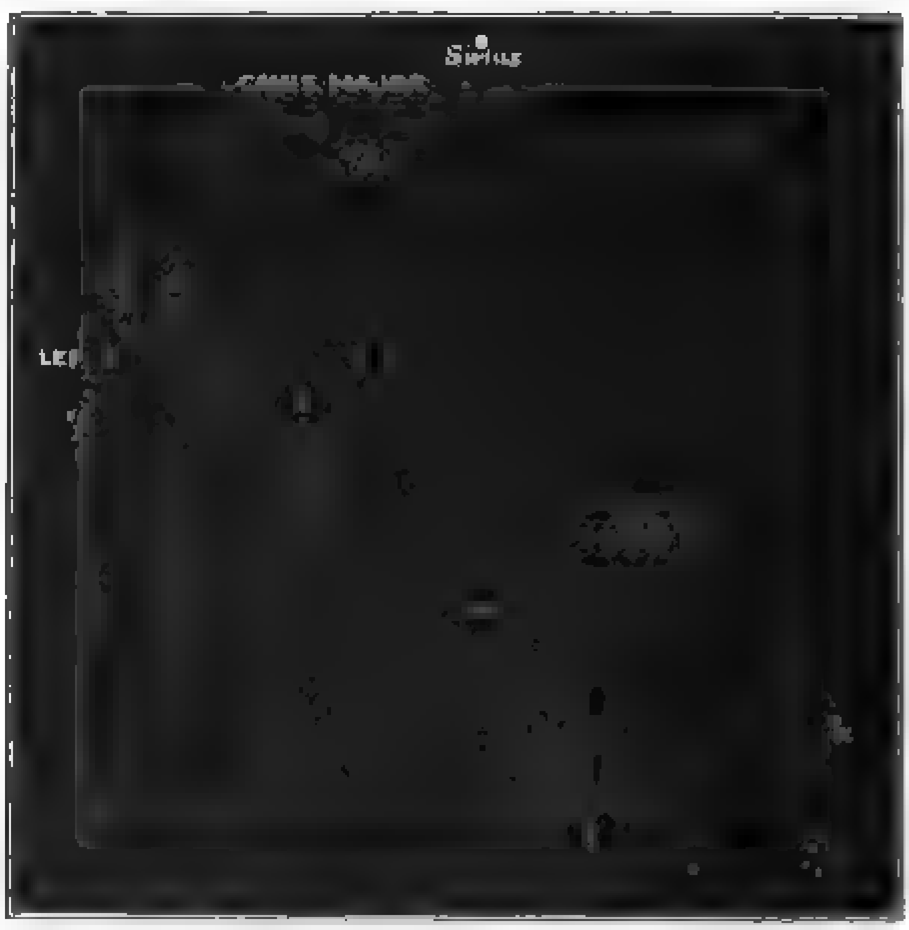
Evening Observations of Comet, 1901 *May* 3-*May* 12. *Mr. Lunt's description.*

The most remarkable feature of the comet, viz. the long faint preceding tail, did not become visible until the comet had emerged from the strong twilight. It was first seen on the evening of Friday, May 3, as a faint ray, scarcely distinguishable, springing from the head at an angle of about 40° to the main tail. This faint tail appeared on two photographs taken with a portrait lens the same evening. On the two following nights, however, as the comet receded further from the Sun and became visible against a darker sky, it was a most conspicuous feature. On the evening of Monday, May 6, the faint tail was seen to be quite four times as long as the main tail and fully 30° in length, but fading away so gradually that it was difficult to place any exact limit to it. At this time the comet attained its maximum splendour as a naked-eye object. With an exposure of 25 minutes a portrait lens showed not only the main faint tail, but two still fainter rays between it and the bright tail, clearly discernible in the lantern slide sent herewith.

The space on each side of the faint rays was filled with faint light, and the darker space between them showed clearly by contrast, although the two faint rays themselves were not so well marked to the eye as they appear in the photograph.

In the accompanying drawing I have endeavoured to represent the dimensions and most striking features of the comet as revealed both by eye observations and photographs. The position is that of the evening of Sunday, May 12, by which time the comet had become intrinsically much fainter, although as seen in a still darker sky it was yet a magnificent object.

The preceding side of the main tail was not then so markedly stronger than the following side as previously, but the tail still streamed off from each side of the nucleus in rays brighter than the space between them, which was filled with fainter light. The faint preceding tail was still fully 25° long, and reached, as shown in the drawing, as far as ζ *Leporis*. The bright tail was about 7° long, and could be traced beyond ζ *Orionis*; its fading beyond this point was much sharper than in the case of the faint tail.



Drawing by J. Lunt. 1901 May 12, 7.15 P.M. Cape Time.

The drawing shows the two short faint rays between the two main tails as they were photographed on May 6, but for clearness somewhat exaggerated in intensity.

The Oxford Photographic Determinations of Stellar Parallax. Reply to Professor Turner. By Sir David Gill, K.C.B., F.R.S., His Majesty's Astronomer at the Cape of Good Hope.

Professor Turner, in meeting my criticisms of the Oxford parallax observations, unfortunately does not touch the principal grounds for doubting the reliability of the Oxford results.

First of all Professor Turner does not refer to Pritchard's fundamentally unsound assumption that, by the methods which Pritchard employed, it is admissible to give independent results for the parallax of the principal star relative to each of two opposite comparison stars. It is obvious that as the scale-value is derived from the distance between the comparison stars *a* and *b*, it must be assumed either that their distance *a b* is constant, or that it varies proportionally to the time. But, if the parallaxes of the comparison stars are not identical, the distance between the stars will vary with the season of the year, and consequently the correction for scale-value (*i.e.* the corrected observed distances) will vary proportionally to this change. In other words, if the comparison stars are situated systematically with respect to the principal star, we should, by Pritchard's methods, obtain the parallax of the principal star relative to the mean of the parallaxes of the two comparison stars, but we have no means of distinguishing, as Pritchard attempted to do, between the parallax of the principal star as derived by measures from star *a* and those from star *b*.

The obvious answer to such criticism is—then, why not take the means of Pritchard's parallaxes from the stars *a* and *b*, and accept the result as the true parallax of the principal star relative to the mean parallaxes of the stars *a* and *b*?

The answer to this question is given in a part of my criticism which Professor Turner omits to quote, and it runs as follows :—

"Although Pritchard frequently vaunts the novelty of his method, he takes no precaution to test its systematic accuracy. By simply taking photographs in the same season of the year at widely different hour-angles he might readily have ascertained whether the *apparent* parallaxes which he derived from observations six months apart, were really, in whole or in part, a function of the hour-angle at which the observations were made. It is obvious, for example, that any displacement of the apparent centre of the star's disc by chromatic dispersion of the atmosphere will, especially in the case of a bright star, be recorded on the photographic plate, and will not be eliminated, as in the heliometer observations, by the observer's superposing the

similarly coloured parts of the spectrum under observation. But amongst all the numerous plates taken and measured by Pritchard's assistants, one can find no published account of the application of any such simple and direct test."

It is the more extraordinary that Professor Turner should have neglected to reply to this criticism, because he seems alive to such sources of error when he says :—

"There may be very good reasons for using different scale-values in different directions quite independent of any hypothesis about distortion of the film. I mention one or two, quite on my own responsibility, not arising out of anything I have seen in Pritchard's work. 1. If the mirror or lens with which the photographs are taken is not an accurate surface of revolution (either essentially or because of flexure), its curvature in different directions, and therefore its focal length, will vary. There are obvious reasons why mirrors should err in this way more than lenses; and it is a curious fact that plates taken with mirrors *do* show some variation in scale in different directions—*e.g.* the photographs of *Eros* taken with the 30-inch mirror at Greenwich (*Monthly Notices*, vol. lix. p. 13). If this is a *vera causa* Pritchard's rule would be essentially correct."

Now, in Pritchard's parallax work, practically all the observations in which the parallax factor has the + sign are made at eastern hour-angles, and all in which that factor has the — sign (from the same star of comparison) in western hour-angles ; or *vice versa.* If then, in Professor Turner's opinion (as also in my own), the flexure of the mirror may play an important part (especially where an angle of a few hundredths of a second of arc embraces the whole quantity to be determined), surely it is not too much to suspect that the effect of such flexure of the mirror may be to displace star-images by quantities which are not strictly symmetrical with the optical axis or with the image of the central star. Thus, as the direction of gravity with respect to the supports of the mirror is very different at eastern and western hour-angles, it was surely necessary to use the obvious precaution of taking photographs at the same season of the year both east and west of the meridian, in order to ascertain whether the apparent displacement of the principal star was due in whole or in part to the effects of flexure in the mirror or to such other causes as I have already indicated.

But Professor Turner's paper reveals other sources of possible error of which no mention is made by Pritchard, and which no one could have foreseen without access to the details of the original observations. For example, he states "that, for the period June 23 to July 1, *when a different mirror was in use*," &c. (the italics are mine). It would be interesting to know if different mirrors were used on other occasions, and what pre-

cautions, if any, were taken to replace the original mirror precisely in the same position relatively to its supports; these are points on which the published results are entirely silent, although they are of crucial importance in estimating the reliability of the results.

As to the figures given by Professor Turner, they apparently present, in the form in which he arranges them, a better agreement than my original inspection of Pritchard's tables led me to think. Unfortunately for the moment our copies of the Oxford observations are in the hands of the binder in England, and I am unable to examine them. But whatever the result of such a re-examination might be, it cannot alter the conclusion that no reliance can be placed on the results, because they afford no data which can serve to distinguish between the displacements caused by instrumental or refraction effects and those which may be due to parallax.

Postscript.—Since the above was written my books have been returned from England, so that I am in a position to complete a reply to Professor Turner's note.

Professor Turner, having rearranged Pritchard's Table XIII., not in order of date but in order of the mean value of the two corrections, appeals to an agreement of the majority of the signs as an answer to my general criticism, viz. "that throughout the series there is little evidence of systematic agreement even in the signs of the scale-value corrections, and their average discordance is very much greater than the systematic error of observation assigned by Professor Pritchard."

The table in question gives, *not* the actual discordances between the measures, but the effect of a difference between the mean scale-value and the instantaneous scale-value as independently determined from measures of the diagonals *a b* and *c d* (for a distance=1000″).

Where the instantaneous scale value is grossly different from the mean scale-value there is a perfect agreement of sign, for it is obvious that by focussing badly enough or in any way adopting a sufficiently erroneous mean scale-value, one could always secure a similarity of sign in the instantaneous scale-value corrections from the two diagonals. Even as matters stand we find that out of 87 pairs of scale-value corrections, the components of which should have the same sign, no less than 24 have opposite signs. To examine the matter more closely, let us take simply the differences between the instantaneous scale-values derived from the stars *a b* and *c d*. These are given in the following table:

Difference of Scale-value (on a distance of 1000″) derived from measures of the diagonals a b and c d.

Values of ($a\,b - c\,d$).

1886.	″		″		″		″
May 30	+0·306	Sept. 15	−0·111	Dec. 2	−0·050	Mar. 16	−·013
June 1	+·098	16	+·166	4	−·233	23	−0·216
4	−·306	17	−·041	7	−·048	27	+·029
8	+·183	18	+·090	9	−·147	Apr. 2	+·035
15	−·334	20	−·056	14	−·078	16	+·402
16	+·213	22	+·170	16	−·372	19	−·290
23	+·592	27	+·098	24	−·372	20	−·226
24	+·269	29	+·079	1887.		25	−·097
28	−·060	30	+·278	Jan. 5	−·090	26	−·083
30	+·591	Oct. 2	−·073	8	−·112	29	−·072
July 1	−·171	6	−·080	10	+·009	30	−·007
Aug. 20	−·034	13	−·004	12	−·138	May 5	+·005
24	+·049	21	−·050	20	−·044	7	+·047
26	−·124	22	−·036	25	−·022	9	+·002
28	+·274	Nov. 3	−·034	31	−·094	10	+·071
29	+·040	5	+·087	Feb. 5	−·100	13	−·065
30	+·079	16	−·173	8	+·071	14	−·176
31	+·014	17	+·066	17	−·067	16	−·329
Sept. 7	−·283	18	+·028	25	+·054	18	−·019
10	+·158	23	−·200	26	−·060	20	−·277
11	−·074	29	+·018	27	+·133	26	−·098
13	−·233	Dec. 1	−·004	Mar. 12	−·097	31	−·048

If the observations were perfect all the quantities of the above table would be zero; let us examine and see how far the errors of the table correspond with Pritchard's estimate of the accidental errors of his observations, or how far they contain other sources of error.

Pritchard's derived values of the probable accidental error of observation are the following:—

For Star *a* to 61_1 Cygni		± 0″·091	(p. 17)
" *a* " 61_2	"	± ·100	(p. 24)
" *b* " 61_1	"	± ·115	(p. 31)
" *b* " 61_2	"	± ·100	(p. 36)
" *c* " 61_1	"	± ·102	(p. 47)
" *c* " 61_2	"	± ·088	(p. 52)
" *d* " 61_1	"	± ·089	(p. 58)
" *d* " 61_2	"	± ·104	(p. 64)
Mean		± 0·100	

Now the sum of the squares of our table of 87 differences is

$$2{\cdot}8082.$$

The *mean error* of a single difference between the scale-values derived from $a\ b$ and $c\ d$ is therefore

$$\sqrt{\frac{2{\cdot}8082}{87}} = \pm\ 0''{\cdot}180$$

or its probable error $\pm\ 0''{\cdot}120$.
But the distance $a\ b$ is $= 2382''$
$c\ d \quad = 2066''$

hence the probable error of the discordance of the distances $a\ b$ and $c\ d$, if reduced by an instantaneous scale-value derived from observations of both pairs, would be

$$\pm\ 0''{\cdot}120 \times 2{\cdot}224 = \pm\ 0''{\cdot}267$$

or the probable error of the measure of the single distance $a\ b$ or $c\ d$ would be

$$\frac{0''{\cdot}267}{\sqrt{2}} = \pm\ 0''{\cdot}190.$$

Now why should this extraordinary difference exist between the probable error of a measure when, on the one hand, the scale-value is determined along a line nearly coincident with the direction of measurement, and when, on the other hand, the scale-value is determined by the mean of two standard distances at right angles to each other?

This fact is the more remarkable because the smaller probable error, $\pm\ 0''{\cdot}10$, is derived from measures between two images, one of which is that of the large and less sharply defined disc of the principal star, whilst the larger probable error, $\pm 0''{\cdot}190$, is derived from measures between the smaller and sharper discs of the comparison stars.

There is only one possible explanation, viz. that some additional fault or cause of error, other than that of accidental error of pointing, is introduced, whose probable effect is $\overset{1}{\sqrt{0{\cdot}19^2 - 0{\cdot}10^2}} = \pm\ 0''{\cdot}162.$

And yet Professor Turner writes as if this error were non-existent, for he remarks "that Sir David Gill sets up this imaginary fault and proceeds to explain it by an equally imaginary cause"!

It is hardly desirable to treat as "imaginary" sources of error by which the amount of purely unavoidable accidental error of pointing is nearly doubled. It seems preferable to endeavour to trace their origin to some cause.

It is all very well arbitrarily to dismiss distortion of the film in the way which Professor Turner says that Pritchard did, viz.

"because he did not believe in this distortion;" that is a very simple way of glossing over a difficulty, but it is not a good plan for getting at the truth. It is also very easy for Professor Turner to deny that distortion of the film can exist; he gives no proof to that effect, but, strangely enough, he next proceeds to give an explanation of the fault which he had just before dismissed as "imaginary" as follows:—

1. "If the mirror or lens with which the photographs are taken is not an accurate surface of revolution (either essentially or because of flexure) its curvature in different directions, and therefore its focal length, will vary. There are obvious reasons why mirrors should err in this way more than lenses; and it is a curious fact that plates taken with mirrors *do* show some variation in scale in different directions—*e.g.* the photographs of *Eros* taken with the 30-inch mirror at Greenwich (*Monthly Notices*, lix. p. 13). If this is a *vera causa* Pritchard's rule would be essentially correct."

2. "If the plate is not strictly normal to the axis of the telescope, there would be variation in scale in different directions. But in this case Pritchard's rule would not be quite correct. If, for instance, the twist was about the line joining *a b*, then the scale-value would remain unaltered for the direction *a b*, and would be altered in the direction *c d*; but the distance from *c* to the star might be increased, while that from the star to *d* was diminished."

3. "If the distances on the plate in the direction *a b* were *measured on a different day* from those in the direction *c d*, then Pritchard's rule would be essentially correct. The small variations would then depend partly on different expansions of the plate with temperature."

With regard to No. 1, Professor Turner apparently thinks that if, from any cause, the focal length of the mirror were different in two directions, the scale-value of a plate, normal to the optical axis of the mirror, would be different in these two directions. This is a mistake, for if the star images are symmetrical the scale-value is defined by the distance of the sensitive surface of the plate from the mirror, and by that only, and the scale-value is quite independent of the focal length. The effect of flexure or dissymmetry of the mirror would only be to produce ill-defined and probably unsymmetrical images in both directions, in pointing on which, errors would be produced in the measures of the standard distances, but such errors would not be linearly proportional to the distance, and consequently Pritchard's rule in that case is incorrect.

With regard to No. 2, Professor Turner's conclusions here are perfectly correct, but unfortunately Pritchard has given no information as to the mode in which the plate-holder is supported or the process by which the plate was adjusted normal to the axis of the mirror. If the mounting of the plate-holder was

reasonably rigid it is improbable that this adjustment would change sensibly between one night and the next for plates taken nearly at the same hour-angle, and yet large differences (far exceeding the probable errors of pointing) do occur in the scale-values derived from the two diagonals under these circumstances. Professor Turner's hypothesis fails to explain this. On the other hand, when the instrument is reversed (as it was at opposite parallactic epochs), it is not impossible that the adjustment of the plane of the plate with respect to the axis may have been changed to a small extent by flexure of the support of the plate-holder.

There are long periods—*e.g.* December 1 to February 5—in which the difference of scale-values $a\,b - c\,d$ (with one small exception) have the same sign, and this may possibly be due to a temporary maladjustment of the plate to the normal plane during that period. Unfortunately Pritchard's published results afford no mention of the dates when such adjustments (if any) were made, and no definite conclusions can be drawn. It is clear, however, that if the plate was liable to such errors the resulting parallaxes would be quite unreliable.

With regard to No. 3, Professor Turner says that if the two diagonals $a\,b$ and $c\,d$ were measured on different days the variations between the scale-values derived from $a\,b$ and $c\,d$ might depend on the different expansions of the plate by temperature. That may be true if we could admit the possibility of sufficient change of temperature, but even then it is only partly true, because Professor Turner omits to take into account the expansion of the steel screw of the De la Rue Macro-Micrometer in terms of which the plates were measured. Changes of temperature would therefore produce changes in measurement depending on the difference between the coefficients of expansion of steel and plate-glass. The difference of these coefficients is

$$0{\cdot}000003 \text{ per degree Centigrade,}$$

corresponding, on a distance of $2000''$ to $0''{\cdot}006$ per degree C. Thus, to produce a difference equal to the probable value of the error which we seek to explain, viz. $\pm\,0''{\cdot}19$, it would be necessary that the two diagonals should be measured at temperatures differing by $32°$ Centigrade $= 58°$ Fahrenheit. Is Professor Turner accustomed to submit his assistants to changes of temperature of this character in the measuring room? Pritchard apparently was not, for he says (*Mem. R.A.S.* xlvii. p. 4), "It was also found that, within the range of the small variations of temperature under which the instrument is used, no correction is required within the limits of the error of observation." On the same page Pritchard also states that "the temperature at the time of observation was noted," so that, although no records of these temperatures are published, Professor Turner can satisfy himself by inspection of the original records whether what Pritchard considers "a small variation of temperature" amounts to $58°$ Fahrenheit. But even if such uncomfortable treatment was

meted out to Pritchard's assistants, it must be remembered that each result is the mean of the measurement of four plates, and therefore Professor Turner's hypothesis would require the still more improbable assumption that in the mean all the *a b* measures were made when the assistants were shivering at 32° Fahrenheit, and all the *c d* measures when they were perspiring at 90° on the same scale, or *vice versa*.

The inadequacy of all Professor Turner's explanations is thus sufficiently proved. I therefore still venture to think that my hypothesis of unequal distortion of the film in different directions is, to say the least of it, a more probable cause of the errors in question.

But, after all, such distortion of the film may, by an easy-minded astronomer, be treated as an accidental source of error in the mean of many plates, although such an assumption does not touch the main grounds of my distrust of the Oxford parallaxes, viz. that, for the reasons given in the first part of this paper, the published results afford no proof whatever that the apparent parallaxes determined by Pritchard are not, in part at least, a mere function of the hour-angle at which the observations were made.

In conclusion, I take advantage of this opportunity to correct a mistake which I have made in the Introduction to vol. viii. part II. of the *Annals of the Cape Observatory*. I have there stated (p. xv) :—

" A precision, at least equal to that of Heliometer observations, has been claimed for the photographic method of determining Stellar Parallaxes. But, apart from their systematic errors, this is very far from being the case in the Oxford measures, even if we accept Pritchard's own result for their probable error, viz. $\pm 0''\cdot 10$ for the single observation.

" The fact is apparently overlooked, that, for the single distances of which the residuals are discussed at Oxford, the maximum parallax factor is 1, whereas in the difference of two opposite distances, as discussed in the modern Heliometer method, that factor is 2. In other words, if the mean of the squares of the Heliometer residuals was the same as that of the Oxford residuals, one Heliometer observation would have four times the weight of one Oxford observation. But we have found (page 144 B) that the probable error of one observation derived from Gill's residuals is $\pm 0''\cdot 071$ as compared with $\pm 0''\cdot 100$ for Oxford ; their corresponding weights with equal parallax factors would therefore be as 2 : 1. Thus, having regard to the weight of the corresponding parallax factors, it would require measures of *eight* Oxford plates — even supposing them free from systematic error—to have the same weight in the determination of parallax as one of Gill's Heliometer measures."

My mistake in this criticism is in having overlooked the fact

that each of Pritchard's results depends on four plates, and not on a single plate as is there assumed.

The amended conclusion of my criticism should therefore be that it requires measures of thirty-two Oxford plates—even if they were free from systematic error—to have the same weight in the determination of parallax as one Heliometer observation.

The Oxford Photographic Determinations of Stellar Parallax. Further Reply to Sir David Gill. By H. H. Turner, D.Sc., F.R.S., Savilian Professor.

Sir David Gill kindly sent me a copy of the above reply, and it may be convenient to have my rejoinder read to the Society at the same time as his paper.

In his volume on stellar parallax Sir David Gill gave three reasons for regarding the Oxford determinations as not "of proved value," which may be briefly stated as follows:

(1) That Pritchard gave separate results for parallax from two comparison stars *a* and *b*, although the distance *a b* had been used to correct each measure for scale-value.

(2) The "chromatic dispersion" objection.

(3) That the figures published by Pritchard gave evidence of distortion of the film, sufficient to render the observations of small value.

In a former paper (*Monthly Notices*, lxi. 5) I considered the third objection only, for as it deals with an actual matter of fact it seemed to me by far the most important. Sir David Gill's reply is chiefly in his postscript, which I will consider presently.

As regards the first and second points which Sir David now pronounces the more important, I am again at variance with him. To the first he has himself supplied "the obvious answer." Surely there is no harm done in giving the results separately? If they are not independent the mean can be taken as Sir David Gill says; and to exhibit them separately has the advantage of showing that there is no numerical mistake, if nothing more.

As regards the second point (between which and the first Sir David Gill traces some connection which I fail to see), it is quite true that Pritchard made no experiments on the effect of chromatic dispersion. It is equally true that Sir David Gill had made none himself at that time, though he had also published parallax work.

The discussion about chromatic dispersion of the atmosphere has come up since then. Indeed, it was not until 1898, when Pritchard had been dead five years, that Sir David Gill initiated

observations to test its reality as a disturbing cause on heliometer observations; and when these were made the whole thing was found to be something very like a mare's nest. Sir David Gill says in his Introduction (*Cape Annals*, vol. viii. pt. II., p. viii.): "I may state at once that the results of these observations go to show that the observer in the process of measurement, unconsciously superposes, *not* the most brilliant points of the two short stellar spectra formed by the chromatic dispersion of the atmosphere, but the two similarly coloured parts of these spectra, and thus the effects of chromatic dispersion are entirely eliminated."

Now here we have in the same breath two distinct things—an observed fact and Sir David Gill's inference from it. The *observed fact* is *merely* that the observations are not affected. The inference as to *why* this happens is not absolutely proved. Atmospheric chromatic dispersion is represented by a quantity $\Delta\beta$, the value of which is as yet undetermined. Sir David Gill has "suggested a method of determining the degree of redness of a star" (he gives, however, the wrong reference, and I have not been able certainly to identify the right reference; in *Cape Annals*, vol. viii. pt. II., p. 125B the reference is given as *Monthly Notices*, 1898 December, p. 98. It is, perhaps, 1897 December, p. 68 ?), but he has apparently got no further than suggesting a *method for determining* $\Delta\beta$. Now I submit that until we know more about the value of $\Delta\beta$ there are two alternative inferences (at least) from the fact that the observations made on δ *Sagittarii* with a heliometer show no effect. One possibility is that $\Delta\beta=0$ to the order required—that chromatic dispersion does not sensibly affect such observations either heliometric or photographic. Sir David Gill prefers to say: We know that $\Delta\beta$ must be sensible, and as it does not apparently affect heliometer observations there must be something in the method of observation which eliminates it. His experience with the heliometer entitles this opinion to the greatest respect, but we must be careful to remember that it is as yet *only* an opinion, and that there are other ways of explaining the observed fact. Therefore it is not quite "obvious" * that photographic observations will be affected just as surely as heliometer observations are not. The experiment has still to be tried, and it is, to say the least, quite possible that atmospheric chromatic dispersion affects photographic parallaxes as little as heliometer parallaxes. Theorising beforehand has been proved misleading in the latter case (although not until a year or two ago) and may be just as misleading in the former.

* Sir David Gill writes: "It is obvious, for example, that any displacement of the apparent centre of the star's disc by chromatic dispersion of the atmosphere will, especially in the case of a bright star, be recorded on the photographic plate, and will not be eliminated as in the heliometer observations, by the observer superposing the similarly coloured parts of the spectra under observation." We have here several assumptions which are by no means obvious.

With regard to the postscript in which Sir David Gill deals with the third point, it is almost sufficient for my purpose to compare his original statement with that which he now substitutes. The original statement was: "Throughout the series there is little evidence of systematic agreement even in the signs of the scale-value corrections." That of his postscript is now: "Even as matters stand we find that out of 87 pairs of scale-value corrections, the components of which should have the same sign, no less than 24 have opposite signs." (The 24 should be 20: I have counted very carefully both in the original table and in my rearrangement of it, *Monthly Notices*, lxi. p. 310.)

Now if Sir David Gill regards these statements as equivalent we have reached the point at which this discussion may stop—where we must "agree to differ." To me there is such an essential distinction between them that I should have expected from him something like a withdrawal of the original statement. With a series of small quantities all near zero a certain number of accidental differences of sign is inevitable; and of the 20 pairs the following 8 for example may be regarded as sensibly zero in both members:—

Aug. 30	$+0''.041$	$-0''.038$
Oct. 2	-0.003	$+0.070$
Oct. 21	-0.046	$+0.004$
Nov. 17	$+0.031$	-0.035
Nov. 29	$+0.016$	-0.002
Dec. 2	-0.047	$+0.003$
Apr. 26	-0.048	$+0.035$
Apr. 29	-0.011	$+0.061$

Of the remaining 12 five belong to the 11 observations at the beginning of the series where I have already explained that there is an error [I may, perhaps, reassure Sir David Gill as to the recurrence of such errors: from August 20 the mirror was not changed], which leaves only seven sensible differences of sign in the 76 observations after the work was satisfactorily begun.

A word as to the phrases "when the instantaneous scale-value is *grossly* different from the mean;" "by focussing *badly* enough;" "a sufficiently *erroneous* mean scale-value." Sir David Gill uses these phrases to characterise differences of scale-value amounting in extreme cases during a year to $0''.6$ in $1000''$, or $.0006$ of the unit. May I ask him to examine the scale-values of the Astrographic Chart plates which he is now taking and measuring at the Cape? Or will he perhaps kindly look at figures already published, say those in *Monthly Notices*, lv. pp. 62 and 63? Here we see compared the scale-values on four plates taken at Greenwich on the *same* night—not of the same region, but of regions overlapping sufficiently well to give a good

comparison—and the scale-values, indicated by the constants a and e, differ to fully half the extent shown in Pritchard's results. It may be remarked that the mere *change of measurer, keeping the plates the same*, can give an apparent change of scale-value from $+\cdot00022$ to $-\cdot00017$ (see the values of e for plates 2059 and 2057 *loc. cit.*). In Pritchard's Table XIII. these quantities would appear as $+0''\cdot22$ and $-0''\cdot17$. If, then, we get such accidental differences for plates taken within a couple of hours on the same night with a refractor (which is known to be more manageable than a reflector), after all the precautions of agate-stops &c. which were devised by the united wisdom of an international conference, and *when* 30 *or* 40 *stars are used*; it seems to me that Pritchard's range of differences for plates taken all the year round with a reflector, as pioneer work, *and with only two stars measured*, is not excessive; and that Sir David Gill's epithets are quite out of place.

I pass to the new examination of Table XIII. undertaken by Sir David Gill in his postscript. He finds the probable error of a measure of distance from Table XIII. and compares it with that found elsewhere by Pritchard (p. 65 of Pritchard's *Memoirs* is better than the scattered references quoted by Sir D. Gill). I remark in reply:—

(1) If the eleven observations May 30 to July 1, in which there is an error (as stated in my former paper) be omitted, the sum of the squares is reduced from $2''\cdot81$ to $1''\cdot62$; and (following Sir David Gill's further work) the probable error of a single distance ab or cd would be $\pm 0''\cdot147$ instead of $\pm 0''\cdot190$. If we are trying merely to make out a strong case against Pritchard we might of course insist on retaining all the printed figures; but if we are really trying to find out the truth of the matter, it is better to exclude figures known to be erroneous.

(2) Sir David Gill assumes apparently that the probable error of a distance is independent of the magnitude of the distance measured. It seems more likely that it is greater for large distances than for small; and this view is confirmed on reference to the figures. Pritchard gives in various tables the "average deviation" of the measured distances; and, on adding up corresponding tables, we find that the average deviation for the half-distances from the central star to the four stars a, b, c, d is about 0·83 times * that for the whole distances ab and cd; and this in spite of the fact that "the smaller probable error" (to quote Sir David Gill's words) "is derived from measures between two images, one of which is that of the large and less

* In Tables XX., XXII., VIII., X., XVII., XV., V., II., XIV., I., Pritchard gives comparable "average deviations" for distances of 955″, 963″, 1002″, 1022″, 1107″, 1115″, 1360″, 1380″, 2065″, and 2380″. The means for the first eight tables are much the same, viz. $0''\cdot183$, $0''\cdot175$, $0''\cdot191$, $0''\cdot199$, $0''\cdot183$, $0''\cdot189$, $0''\cdot185$, $0''\cdot185$, mean of all $0''\cdot186$. The means for the last two are $0''\cdot219$ and $0''\cdot229$, mean of both $0''\cdot224$. Ratio of $0''\cdot186$ to $0''\cdot224$ is 0·83.

sharply defined disc of the principal star, whilst the larger is derived from measures between the smaller and sharper discs of the comparison stars." Indeed, by using this factor 0·83 as it stands, we shall not only reduce the probable error for a distance of $2200''$ so as to be properly comparable with one of half that distance, but we shall at the same time compensate directly the unknown disturbance of the results due to the large disc of the central star, which Sir David Gill leaves as an outstanding balance in his own favour. This factor 0·83 then reduces our probable error found from the comparison of *ab* and *cd* still further from $0''\cdot147$ to $0''\cdot122$, and the probable effect of the "additional fault or cause of error" is reduced from $\sqrt{(0''\cdot19)^2-(0''\cdot10)^2}=\pm0''\cdot16$ to $\sqrt{(0''\cdot122)^2-(0''\cdot100)^2}=\pm0''\cdot07$ which is a sort of quantity one might quite reasonably expect.

(3) Accepting this remainder as a real difference, I must still demur to Sir David Gill's statement that I have written as if this difference (he calls it an "error") were non-existent. On the other hand, I spent some paragraphs in considering possible causes for it, which he has quoted. When I spoke of an "imaginary fault" I was referring to quite another matter, viz. the fault originally assigned to the observations by Sir David Gill in saying that "there is little evidence of systematic agreement even in the signs." I have already pointed out that his revised statement ("we find that out of 87 pairs no less than 20 have opposite signs") is very different from the former; and there is the same wide difference between the "fault" I called imaginary and the discrepancy, now reduced to an amount not surprising, for which I have already assigned three other possible contributing causes at least. And, if Sir David Gill wishes, I will admit as a possible fourth the "distortion of the film." I have called it an "imaginary cause," and will still do so; for its sensible existence has still to be proved. That it cannot be the sole or even the chief cause of the discrepancy under consideration follows from the fact to which Sir David Gill himself draws attention, viz. that "there are long periods in which the differences of scale value have the same sign." It will require some ingenuity to explain how distortion of the film can act in this way.

Of the other three causes suggested by me let me take first that which enables Sir David Gill to contribute to the gaiety of nations—I allude to the "freezing and perspiring" paragraphs. It seems sad to have to knock the bottom out of a joke; for we get so few in astronomy, especially in such serious work as parallax work. But the whole point of this joke lies in its coefficient, and I cannot accept the coefficient. First of all, where does Sir David Gill's $0''\cdot19$ come from? Surely he means $\sqrt{(0''\cdot19)^2-(0''\cdot10)^2}$ or $0''\cdot16$ as above? He would probably have corrected this in proof (as also the 24 for 20 earlier mentioned. I should have gladly corrected these slips for the distant author, but he has rendered this course impracticable by

laying such stress on the figures), and then he would have contracted his range of 58° F. to 49° F. But a further contraction is necessitated by the little revision of figures I have sketched above—bringing the 49° down to 21°. I must finally submit that temperature is by no means called upon to explain the *whole* discrepancy; half or a third will be quite a respectable contribution, and so we get down to 10° or 7° perhaps, which is quite sober earnest.

Next as regards the tilt of the plate: "If the mounting of the plate-holder was reasonably rigid it is improbable that this adjustment would change sensibly between one night and the next for plates taken nearly at the same hour-angle." Sir David Gill is making no allowance for the variable curvature of the plate, which is an important factor in these matters. Once again I would refer him with confidence to his own results or to such published figures as have been already quoted; and I will ask him to remember that the mounting of a plate-holder in a reflector cannot be so rigid as in a refractor. Finally, my suggestion about the curvature of the mirror he calls a mistake. Possibly; but I am not convinced by what he says. The point is not an easy one, and actual experiment will be the best test; but I will venture to put down the way in which it appears to me. If scale value has any uniform meaning, we may suppose the mirror replaced by a pinhole, from which the rays diverge to the plate. The scale value will then depend simply on the distance of this pinhole from the plate. Now *where* is this pinhole? Is it absolutely *at* the surface of the mirror? It must be close to it, but I do not feel at all sure that it is not at a small distance from it. We can scarcely decide by simple theory; for the measurement of images and even the actual meaning of the word "focus" are matters of compromise, on lines only imperfectly worked out theoretically; and the position of this hypothetical pinhole depends on them. Hence, speaking tentatively, I would point out that if the place of this representative pinhole is not rigidly *at* the surface of the mirror, its distance from it must depend on the curvature (there is nothing else for it to depend on); consequently, if the curvature is different in different directions we shall have different representative pinholes for these directions, *i.e.* different scale values. Experiments would settle the point, but it is not easy to settle it theoretically. To prevent possible misunderstanding, I may say that I consider all the following points to be proper subjects for experiment:

(1) Photographic distortion of the film.
(2) Atmospheric chromatic dispersion.
(3) Effect of flexure of mirror on scale value.

Of none of these have I intentionally denied the *possible* existence; I will even affirm their existence. But to what extent? The whole point is, What is their magnitude?

The discussion has already reached a greater length than I anticipated; for, as I have already said, it is not my intention to undertake a systematic re-examination of Pritchard's work. Starting such work now one would do it differently perhaps; we have had ten years' experience in photographic measurement since Pritchard began. But that his work can be dismissed in the cursory manner of Sir David Gill's Introduction I do not believe. It is at least worthy of careful examination. For one thing it is (so far as I know) even yet the only considerable research on stellar parallax by photography actually carried out. Many peeple have talked of doing such work before and since, but as compared with talk, an actual piece of work done is entitled to a measure of respect.

The Normal Equations that arise in the usual Schemes of Observation for Division Errors and their Solutions. By P. H. Cowell, M.A.

Notation.

The circle of 360° is supposed divided into n arcs of $\frac{360^\circ}{n}$ each; and the error of the division $r\,\frac{360^\circ}{n}+A^\circ$ is denoted by x_r, where r takes all the values 1, 2 . . . n. At the first setting of the circle the $s+1$th division at the $A+(s+1)\,\frac{360}{n}$th degree is supposed to be under the sth microscope. In some cases s will take all integral values from 1 to n, but in other cases s will only take some of these values. Between the settings the graduated circle is supposed to be turned in such a way that the $s+t$th division at the $A+(s+t)\,\frac{360}{n}$th degree is under microscope s. The series of observations will be complete when there have been n settings of the circle, but in order to eliminate time changes it is usual to at once repeat the observations in the reverse order. Any uniform change is eliminated either by taking the mean of corresponding readings, that is to say, readings equidistant from the middle of the double series, or preferably by solving each single series separately, and taking the mean of the final results, whose discordance indicates the amplitude of the changes that may have occurred.

It is henceforth assumed that a single series of observations is being dealt with.

The division error x_r is defined as the amount by which the circle appears to read too large in consequence of division error. The sth microscope is supposed subject to an error of position

y_n causing the reading under the microscope to be too large. At the tth setting the circle will be supposed to have been turned too far by a distance z_t, so that all the readings at the tth setting are on this account z_t larger than was intended.

The Equations.

If $c_{s.t}$ be the reading under the sth microscope at the tth setting, the typical equation is

$$x_r + y_s + z_t = c_{st}$$

where

$$r = s + t$$

and r or t may have any integral value from 1 to n, and s may have certain selected values according to the number and positions of the microscopes. Let m be the number of microscopes; then we have mn equations of the above type to determine $2n+m$ quantities, of which two, say x_n and z_n, are arbitrary. If, therefore, mn is greater than $2n+m-2$, we have more equations than unknown quantities, and theoretically normal equations should be employed. Since, however, the normal solution is the best, that is to say, of maximum accuracy, any solution, where the fundamental equations are combined not very differently, will have an accuracy hardly appreciably less; there is, on the other hand, a risk that the fundamental equations, if combined arbitrarily, may be combined in a way that may give a very erroneous result. As an illustration, if $x=1$ and $x=3$ be two equations of equal weight, the normal solution gives $x=2$; but any other value for x may be obtained by unequal weighting. To return to the system of equations under discussion, if all the quantities except x_r be eliminated in an arbitrary fashion is there any guarantee that the process is not equivalent to assigning a negative weight to some of the equations?

The Normal Equations.

The normal equations formed in the usual manner are:

$$\begin{aligned} mx_r \quad &+ \Sigma y + \Sigma_s z_{r-s} = \Sigma_s c_{s.r-s} \\ \Sigma x \quad &+ n y_s + \Sigma z \quad = \Sigma_t c_{s.t} \\ \Sigma_s x_{s+t} &+ \Sigma y + m z_t \quad = \Sigma_s c_{s.t} \end{aligned}$$

When the suffix of Σ denotes the symbol for all values of which the summation is to be taken, and when the suffix is omitted, the summation includes all quantities expressed by the same letter.

It is to be remarked that there are $2n+m$ equations written above to determine $2n+m$ quantities of which two are arbitrary. As, however, the sum of all the equations in a group is the same

for each of the three groups, there are only $2n+m-2$ independent equations.

As the y's do not occur in the first and third groups except in the single form Σy, it is clear that we may treat the m equations of the second group as determining the m quantities y; we may therefore suppress this group, and we are left with

$$\begin{aligned} mx_r \quad + \Sigma y + \Sigma_s z_{r-s} &= \Sigma_s c_{s.r-s} \\ \Sigma_s x_{s+t} + \Sigma y + mz_t \quad &= \Sigma_s c_{s.t} \end{aligned}$$

or $2n-1$ independent equations, to determine n quantities x, n quantities z, and one quantity Σy, or $2n+1$ quantities in all, of which two, x_n and z_n say, are arbitrary.

Particular Cases.

(i.) $n=6$; $m=6$.

The normal equations are

$$\begin{aligned} 6x_r &= \Sigma_s c_{s.r-s} \\ 6z_t &= \Sigma_s c_{s.t} \end{aligned}$$

where the arbitrary constants have been chosen so that

$$\Sigma x = \Sigma z = -\Sigma y.$$

The most convenient form for computation is to enter the 36 readings in a square of six by six, the readings in the same row corresponding to the same setting of the circle, and the readings in the same column to the same division of the circle, and the readings of the same microscope will fall on a line parallel to one of the diagonals.

Let S denote a sum taken vertically, and S′ a sum taken horizontally; then

$$6x_r = \mathrm{S}_r \qquad 6z_t = \mathrm{S}'_t$$

and as a numerical check S′S=SS′, or the sum taken horizontally of the sums S is equal to the sum taken vertically of the sums S′.

If the weight of a single reading be unity, the weight of a determination of division error is 6.

(ii.) $n=8$; $m=7$.

Let the missing microscope be the last one; the case supposed sometimes occurs when it is inconvenient or impossible to mount an eighth microscope.

The normal equations are

$$\begin{aligned} 7x_r - z_r \quad &= \Sigma_s c_{s.r-s} \\ -x_t + 7z_t &= \Sigma_s c_{s.t} \end{aligned}$$

where the arbitrary constants are chosen so that

$$\Sigma x = \Sigma z = -\Sigma y.$$

Arrange the 56 readings in a square of eight by eight with a diagonal empty to correspond to the missing microscope. As before, readings on the same row correspond to the same setting; readings in the same column to the same division. Let S denote the sum of the seven quantities in a column, S′ the sum of the seven quantities in a row; then

$$7x_r - z_r = S_r$$
$$-x_r + 7z_r = S'_r;$$

then eliminating z_r

$$48x_r = 7S_r + S'_r$$

To finish the computations, multiply the quantities S by 7 in a row beneath them, and add the quantities S′. As a check $S'S = SS'$ as before; also $48\Sigma x = 8S'S$.

If the weight of a single reading be unity, the weight of a determination of division error is $\frac{1152}{175} = 6{\cdot}58$.

(iii.) $n = 24$; $m = 8$, s taking the values 1, 4, 8, 12, 13, 16, 20, 24. This is a usual way of obtaining the division errors for 15°. It is usually preceded by a determination of every 60°. In fact, by suppressing the readings of the microscopes $s = 1$, $s = 13$, we arrive at four repetitions of case (i.), so that the division errors of four sets of divisions, each set being a group of six 60° apart, may be determined as in case (i.) each to an arbitrary constant. It is the function of the two microscopes $s = 1$, $s = 13$ to connect the four arbitrary constants of the four groups.

The normal equations are—

$$8x_r \quad + \Sigma y + \Sigma_s z_{r-s} = \Sigma_s c_{s.r-s}$$
$$\Sigma_s x_{s+t} + \Sigma y + 8z_t \quad = \Sigma_s c_{s.t}$$

The eliminations, in order to obtain the values of the quantities X separately, are difficult to perform, and therefore, for the reasons given above, equations for four quantities X_p ($p = 1, 2, 3, 4$)

where $$X_p = \Sigma_k x_{4k+p} \; (k = 1, 2, 3, 4, 5, 6)$$

will be formed. A similar meaning being attached to the symbols Z_p and $C_{s.p-s}$ and $C_{s.p}$, we have, by adding the normal equations in groups of six—

$$8X_p \quad + 6\Sigma y + \Sigma_s Z_{p-s} = \Sigma_s C_{s.p-s}$$
$$\Sigma_s X_{s+p} + 6\Sigma y + 8Z_p \quad = \Sigma_s C_{s.p}$$

Now $$\Sigma_s Z_{p-s} = 6Z_p + 2Z_{p-1}$$
$$\Sigma_s X_{s+p} = 6X_p + 2X_{p+1}$$

Again, the $24 \times 8 = 192$ readings of the complete set may be grouped as follows: Four groups of 36 readings each, namely, the readings of the six symmetrical microscopes at the pth, $p+4$th, $p+8$th, $p+12$th, $p+16$th, $p+20$th settings; let the

sum of one group of 36 readings be C_p. Four groups of 12 readings each, namely, the readings of the two unsymmetrical microscopes at the same settings; let the sums be denoted by C'_p ($p=1, 2, 3, 4$), then it is not difficult to see that

$$\Sigma_s C_{s\,.\,p-s} = C_p + C'_{p-1}$$
$$\Sigma_s C_{s\,.\,p} = C_p + C'_p$$

and the eight normal equations become:

$$8X_p + 6\Sigma y + 6Z_p + 2Z_{p-1} = C_p + C'_{p-1}$$
$$6X_p + 2X_{p+1} + 6\Sigma y + 8Z_p = C_p + C'_p$$

or eliminating the Z's:

$$12(2X_p - X_{p-1} - X_{p+1}) = 8C_p + 8C'_{p-1} - 6C_p - 6C'_p - 2C_{p-1} - 2C'_{p-1}$$
$$= 2C_p - 2C_{p-1} + 6C'_{p-1} - 6C_p$$

Solving this difference equation

$$6(X_p - X_{p-1}) = 3C'_{p-1} - C_{p-1}$$

plus an arbitrary constant, which is determined by the condition

$$\Sigma(X_p - X_{p-1}) = 0.$$

Hence the following precepts for computing are obtained :—

Form the four quantities $D_p = 3C'_p - C_p$ (to do this subtract the sum of the readings of the six symmetrical microscopes for each setting of the circle from three times the sum of the two unsymmetrical readings, and then add the 24 quantities thus obtained in four groups of six); then

$$6X_p = \tfrac{3}{8}(D_{p-1} - D_p) + \tfrac{1}{8}(D_{p+2} - D_{p+1})$$

and if the weight of a single observation be unity, the weight of the determination of $\frac{X_p}{6}$ is $\frac{144}{5} = 28{\cdot}8$.

On a modified form of Revolving Occulter for adapting the exposure of the Sun's Corona to its actinic intensity at all distances from the Moon's limb. By Professor David P. Todd, Director of Amherst College Observatory.

(*Communicated by the Secretaries.*)

Fifty years have now elapsed since the Sun's corona was first daguerreotyped. A heliometer with uncorrected objective was used, and it is not certain that the clockwork was sufficiently good to have prevented the blurring inseparable from the long exposure required by the relatively insensitive silver iodised surface. Still, the daguerreotype of the corona of 1851 compares very favourably with many photographs of the most recent

eclipses, although the latter are often taken with specially corrected objectives, practically perfect clock-motion, and relatively short exposure.

De la Rue, in the Spanish eclipse of 1860, made the next successful attempt, using wet collodion plates; and so fine were his photographs that they proved conclusively the connection of the corona with the Sun and not the Moon, because their detail was so sharp that the dark disc of the latter was shown passing over one filament after another; and subsequent measurement showed that these were stationary with reference to the Sun throughout totality.

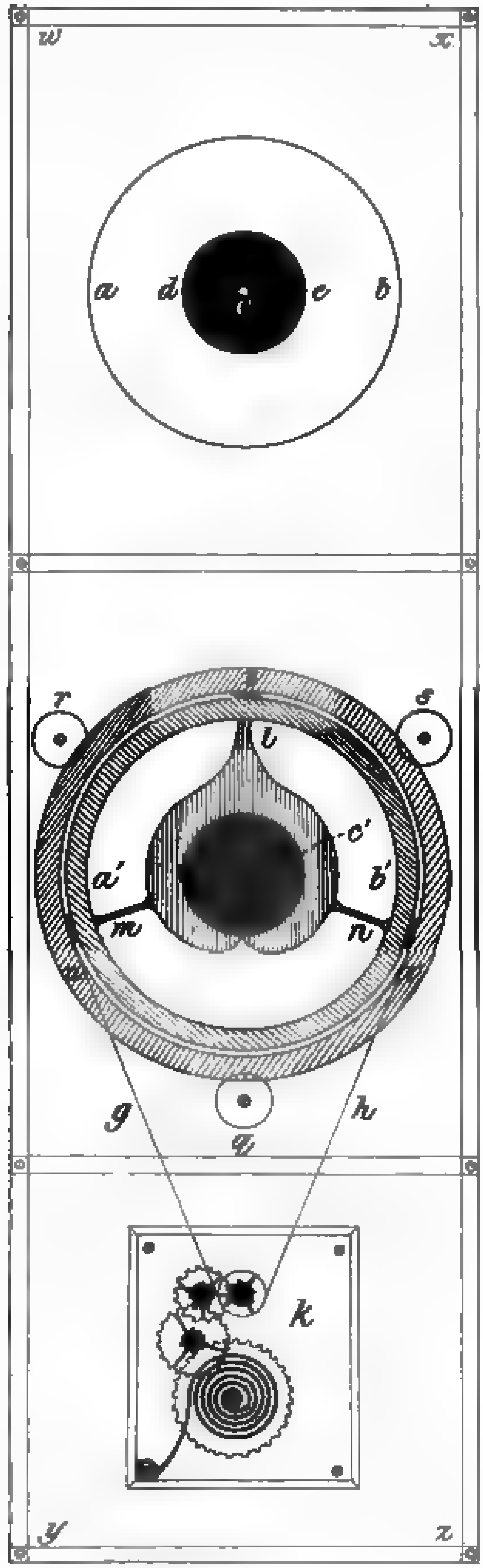
Lord Lindsay's Indian expedition in 1871 brought back perhaps the finest photographs of the corona ever taken—again wet plates, with excellent lenses and clockwork, and the expert manipulation of his photographer, Mr. Davis.

I think it an open question whether the old-fashioned wet-plate pictures of the corona will ever be surpassed by the modern and more convenient dry-plate ones, except by the adoption of some device, mechanical and automatic, for reducing the excessive actinic effect of the innermost corona, and the consequent halation obliterating all detail. To this end I constructed a device for photographing the corona in rings, described elsewhere;* but being satisfied that the scheme of Mr. Burckhalter is superior to it, I have re-designed and constructed a revolving occulter for the eclipse of 1901 May 18. It will be seen that I have overcome the most serious objection to the original form of the device—namely, the necessity for perforating the sensitive glass plate.

The illustration (Plate 16) readily shows how this is accomplished. A light frame, *w x y z*, slides in grooved ways about one inch inside of the focal plane. The circular field is *a b*, the size of the Moon *d e*; and when the occulter is not in use the frame is pulled out so that *d e* is central over *c*. Photographs are here taken, as usual, so as to compare directly with those taken later by the same instrument, but modified by the occulter.

By pushing in the frame (up in the figure) to an accurate stop, which movement takes but half a second, *c′* takes the position in the field formerly occupied by *c*. The clockwork, *k*, is set going, and the exposure begins. By means of a light cord, *g h*, running round a pinion of *k* and the rim, *t u v*, the latter is revolved several turns per second. This rim is, of course, made very light, spun from thin aluminium, and exactly circular in all its sections. Its weight is but two ounces, and instead of turning on a central pivot, its outer edge slips through three accurately-adjusted friction wheels, *q r s*. The best disposition of these is shown in the illustration. One of them, *q*, should be as near as possible to *k*. The interior of this whirling ring has a groove, past which it is possible to slip, accurately and firmly, a black disc, *a′ b′*, touching the rim at only three points. The black discs

* *Stars and Telescopes*, Sampson Low, Marston & Co., 1900, p. 463.


w
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are cut to any figure desired, from stiff corrugated strawboard packing, double faced. This is very strong; the finished disc or occulting screen weighs less than a half-ounce, and to change one disc for another occupies but four or five seconds.

The critical part of the apparatus is of course the heart-shaped figure within a' b', and attached to it at the points l, m, and n.

By carefully calculating the relative arc-values of exposure, central about c', it is easy to lay out a curve, point by point, and cut the corresponding disc, which, as the occulter whirls round, shall give any desired integral of exposure to the corona on a single plate, from $0^s.1$ close to the Moon's limb up to 30^s at $30'$ distance.

The extraordinary length of totality in 1901 affords a ready opportunity for the substitution of several discs, calculated on different data as to the actinic intensity of the coronal light at various distances from the limb. There will be abundant time also for two or three exposures with each type of occulting disc. The size of the Moon's disc in the instrument I have adapted is $1^m.8$—a 12-inch metal speculum of 15 feet focal length. For the photographic part I am depending upon the Standard Eastman films backed, as exhibiting less halative effect than glass plates. The mirror has a simple mounting moved by the glycerine clock, which affords that readiness of quick and accurate adjustment necessary to get the Moon's image exactly central round the c' of the occulter, and to maintain it there during the long totality.

What the new occulter is capable of doing I hope to be able to tell better after the eclipse is over. In rebuilding it I should make two further improvements: (*a*) to put the occulting disc within a few millimetres of the focal plane; (*b*) to rotate it by a clockwork whose rate is instantly changeable within wide limits, as I think the occulter should turn round not only at a perfectly uniform rate, but should make only one complete rotation during a single exposure, whatever its length. But these changes must be reserved for 1904.

Mean Areas and Heliographic Latitudes of Sun-spots in the year 1900, deduced from Photographs taken at the Royal Observatory, Greenwich, at Dehra Dûn (India) and in Mauritius.

(*Communicated by the Astronomer Royal.*)

The results here given are in continuation of those printed in the *Monthly Notices*, vol. lxi. p. 3, and are deduced from the measurements of photographs taken at the Royal Observatory, Greenwich; at Dehra Dûn, India; and at the Royal Alfred Observatory, Mauritius.

Table I. gives the mean daily areas of umbræ, whole spots, and faculæ for each synodic rotation of the Sun in 1900; and Table II. gives the same particulars for the entire year 1900 and the eleven preceding years for the sake of comparison. The areas are given in two forms: first, projected areas, that is to say, as millionths of the Sun's apparent disc; and, next, areas as corrected for foreshortening, the areas in this case being expressed in millionths of the Sun's visible hemisphere.

Table III. exhibits for each rotation in 1900 the mean daily area of whole spots, the mean heliographic latitude of the spotted area, and the mean distance from the equator of all spots; and Table IV. gives the same information for the year as a whole, similar results from 1889 to 1899 being added, as in the case of Table II. Tables II. and IV. are thus in continuation of the similar tables for the years 1874 to 1888 on pp. 381 and 382 of vol. xlix. of the *Monthly Notices*.

The rotations in Table I. and Table III. are numbered in continuation of Carrington's series (Observations of Solar Spots made at Redhill by R. C. Carrington, F.R.S.), No. 1, being the rotation commencing 1853 November 9. The assumed prime meridian is that which passed through the ascending node at mean noon on 1854 January 1, and the assumed period of the Sun's sidereal rotation is 25·38 days. The dates of the commencement of the rotations are given in Greenwich civil time, reckoning from mean midnight.

TABLE I.

No. of Rotation.	Date of Commencement of each Rotation.	No. of days on which Photographs were taken.	Mean of Daily Areas. Projected. Umbræ.	Whole Spots.	Faculæ.	Corrected for foreshortening. Umbræ.	Whole Spots.	Faculæ.
	1899.							
618	Dec. 7·76	27	10	70	236	7	51	277
	1900.							
619	Jan. 4·09	27	16	99	161	10	63	182
620	Jan. 31·42	25	18	133	327	13	114	376
621	Feb. 27·77	26	31	155	215	26	136	242
622	Mar. 27·08	27	22	124	221	15	87	257
623	Apr. 23·35	28	50	253	312	30	154	388
624	May 20·58	26	19	91	241	14	68	296
625	June 16·78	27	52	163	104	51	134	152
626	July 13·99	27	16	58	126	10	39	137
627	Aug. 10·20	27	6	28	36	5	23	48
628	Sept. 6·45	27	8	21	95	5	13	120
629	Oct. 3·72	28	54	210	88	42	159	104
630	Oct. 31·01	27	5	18	66	3	12	77
631	Nov. 27·32	28	0	0	14	0	0	23

TABLE II.

Year.	No. of days on which Photographs were taken.	Mean of Daily Areas. Projected. Umbræ.	Whole Spots.	Faculæ.	Corrected for foreshortening. Umbræ.	White Spots.	Faculæ.
1889	360	17·9	103	107	13·1	78·0	131
1890	361	21·3	133	273	15·5	99·4	304
1891	363	120	745	1322	86·2	569	1412
1892	362	255	1596	3230	186	1214	3270
1893	362	327	1983	2287	234	1464	2404
1894	364	317	1728	1666	231	1282	1877
1895	364	237	1330	2059	169	974	2278
1896	364	127	745	1243	90	543	1410
1897	364	122	695	977	88	514	1149
1898	363	93	532	767	64	375	891
1899	364	27	159	297	18	111	337
1900	360	22	101	150	17	75	180

TABLE III.

No. of Rotation.	Date of Commencement of each Rotation.	No. of Days on which Photographs were taken.	Spots north of the Equator. Mean of Daily Areas.	Mean Heliographic Latitude.	Spots south of the Equator. Mean of Daily Areas.	Mean Heliographic Latitude	Mean Heliographic Latitude of Entire Spotted Area.	Mean Distance from Equator of all Spots.
618	1899. Dec. 7·76	27	29	7°·16	22	11°·61	− 0°·97	9°·09
619	1900. Jan. 4·09	27	56	7·84	7	11·32	+ 5·65	8·24
620	Jan. 31·42	25	105	9·48	10	9·63	+ 7·89	9·50
621	Feb. 27·77	26	2·5	4·38	134	11·99	− 11·69	11·85
622	Mar. 27·08	27	15	7·18	72	11·13	− 8·02	10·46
623	Apr. 23·35	28	24	4·35	130	7·57	− 5·57	7·08
624	May 20·58	26	56	3·83	11	8·06	+ 1·86	4·53
625	June 16·78	27	65	4·38	69	6·95	− 1·43	5·70
626	July 13·99	27	4	8·09	36	6·43	− 5·09	6·58
627	Aug. 10·20	27	14	3·49	9	13·13	− 3·29	7·43
628	Sept. 6·45	27	3	7·95	9	4·71	− 1·54	5·52
629	Oct. 3·72	28	0·0	...	159	5·56	− 5·56	5·56
630	Oct. 31·01	27	12	9·52	0·8	6·95	+ 8·49	9·36
631	Nov. 27·32	28	0·0	...	0	...	...	...

TABLE IV.

Year.	No. of Days on which Photographs were taken.	Spots north of the Equator. Mean of Daily Areas.	Spots north of the Equator. Mean Heliographic Latitude.	Spots south of the Equator. Mean Daily Areas.	Spots south of the Equator. Mean Heliographic Latitude.	Mean Heliographic Latitude of Entire Spotted Area.	Mean Distance from Equator of all Spots.
			°		°	°	°
1889	360	5·0	7·26	73·0	11·90	−10·68	11·61
1890	361	53·1	22·20	46·3	21·75	+ 1·73	21·99
1891	363	401	20·49	169	19·91	+ 8·52	20·31
1892	362	607	15·09	607	21·69	− 3·29	18·39
1893	360	517	14·91	941	14·26	− 3·93	14·49
1894	364	543	12·31	739	15·56	− 3·75	14·18
1895	364	565	14·26	409	12·54	+ 3·01	13·54
1896	364	203	13·60	340	14·77	− 4·15	14·33
1897	364	196	8·32	318	7·73	− 1·62	7·96
1898	363	110	9·82	266	10·77	− 4·75	10·49
1899	364	23	6·18	88	10·43	− 6·95	9·54
1900	360	26	6·61	49	8·34	− 3·12	7·74

The principal features of the record for 1900 are :—

1. The decline in areas of umbræ, whole spots and faculæ has been continued, the mean daily spotted area being about two-thirds, and the amount of faculæ about half the corresponding quantities for 1899.

2. The decrease in the area of the umbræ is slight.

3. The northern hemisphere has, as in 1899, been much the less active, giving only one-third of the total mean spotted area.

4. Only seven groups seen for at least ten days and with an average area exceeding 100 millionths of the hemisphere appeared during the year, viz. :—January 28–February 6, March 26–April 17, April 27–May 6, April 27–May 6, May 21–June 1, June 15–24, October 17–28. The second and fifth of these groups may be identified with groups seen in a previous rotation ; the third and fourth which form one large group with a group in a subsequent rotation.

5. There has been a further approach towards the equator in the mean latitude of spots.

6. Out of 360 days on which photographs were obtained there were 191 days without spots, 205 without faculæ, and 79 of these days were without spots or faculæ.

7. The minimum does not appear to have been reached in 1900 ; at the date of this paper (1901 July) no spot of high latitude marking the beginning of a new cycle has been seen.

1901 *July*.

Sun-spots and Magnetic Disturbance. By William Ellis, F.R.S.

The paper by Father Sidgreaves, appearing in vol. 54 of the *Memoirs of the Royal Astronomical Society*, "On the Connexion between Solar Spots and Earth-magnetic Storms," takes up a difficult subject. The general correspondence between the rise and fall of solar spots and terrestrial magnetism, whether measured by the variation of magnetic diurnal range or by the number of days of magnetic disturbance and storm, has been sufficiently well shown; but as regards correspondence in individual particulars, little that is really satisfactory has been so far evolved. The Rev. A. L. Cortie (*Monthly Notices* for 1900 May), in treating of the duration of Sun-spots, has shown that numerous groups are seen through several successive rotations of the Sun, but the author of the paper first mentioned has carried the matter further, by undertaking a considerable discussion of the question of the extent to which relation between individual solar spots and terrestrial magnetic disturbances and storms may be traced. Any serious consideration of this question deserves attention, since such work usually involves much labour. The general effect observable by those who have studied the matter is that, in our latitude, there may be at one time a large solar spot with great magnetic disturbance accompanied by remarkable aurora (as in 1882 November and in 1898 September), when Sun, Earth, and Earth's atmosphere are all involved; at another time a considerable solar spot may appear without accompaniment of unusual magnetic movement; and again magnetic disturbance may occur without any noteworthy spot.

Lord Kelvin, in his presidential address to the Royal Society in 1892, estimating the amount of work which must be done at the Sun to produce a terrestrial magnetic storm, considered the result obtained as absolutely conclusive against the supposition that terrestrial magnetic storms are due to magnetic or other action of the Sun, adding that it seems as if we may be forced to conclude that the supposed connection between magnetic storms and Sun spots is unreal, and the seeming agreement between the periods a mere coincidence. But to show that the Sun does not directly produce magnetic disturbance was not to prove that no relation existed, or that the agreement between the periods was accidental. The fact of general relation, however it is to be explained, is so far evident that theory must take account of it (*Proc. Royal Society*, vol. lxiii. p. 64). Lord Kelvin, in demonstrating the improbability of the existence of direct connection, may be understood to have had more in mind such a circumstance as the simultaneous observation by Carrington and Hodgson of an outburst on the Sun on 1859 September 1, corresponding in time with a magnetic movement shown on the photographic magnetic records, to which indeed he had referred in an earlier

portion of his address. Carrington, one of the observers of the solar movement, while considering the phenomena as deserving of notice, said that "he would not have it supposed that he even leans towards hastily connecting them." An occurrence so striking attracted attention, but unfortunately the narrative became repeated with exaggeration of statement, inducing a belief in direct connection. But time at last showed that here was apparently misconception, for although the Sun, in the ordinary routine of solar work, has since been unremittingly watched, and a continuous photographic magnetic record also maintained, similar conditions have not been again observed. The magnetic motion, in the case in question, was in itself in no way remarkable, was indeed slight, and of a character and magnitude such as often occurs, and much greater movements are also sufficiently numerous, but yet direct correspondence has not been made out. The apparent connection, thus having in after years received no further confirmation from observation, was shown also by Lord Kelvin thirty-three years afterwards to be from other considerations improbable. But, as before said, the general relation, both with variation of diurnal range and with frequency of magnetic disturbance and storm, is undoubted.

A later sentence in the same address runs: "We have at present two good and sure connections between magnetic storms and other phenomena: the aurora above, and the earth currents below, are certainly in full working sympathy with magnetic storms." The observation of earth currents at Greenwich Observatory, continued through many years, entirely supports this statement. When the ordinary diurnal magnetic variation is alone present, whether at maximum or minimum of Sun spots, earth currents are extremely feeble; but the appearance of magnetic disturbance, superposed on the ordinary diurnal movement, brings up at once a corresponding active earth current, and in very pronounced cases there may be also aurora. The magnetic irregularity and the active earth current are twin manifestations of an energy in the sense that one is never present without the other. Even a small superposed magnetic movement occurring suddenly is at once accompanied by a brisk little earth current. The correspondence is complete, the earth current being ever present with magnetic irregularity or storm. The same condition is found to exist at other places.

Thus in our latitude we may have (1) a large Sun-spot accompanied by magnetic disturbance + earth current, and, it may be, aurora—that is, the disturbing element involves both Sun and Earth; or (2) a considerable Sun-spot may appear with magnetic quiet; or (3) magnetic disturbance + earth current with solar quiet. In case 2 the Sun only is involved, and in case 3 the Earth only. Father Sidgreaves appears now to make out that the greater the Sun-spot the more frequently relatively is there accompaniment of magnetic disturbance or storm; not that there is direct correspondence, but that during a certain period there is

disturbance over a large field, influencing both Sun and Earth, the Sun-spot, or whatever produces it, being usually a determining element, not in all cases apparently, since a considerable spot may appear without magnetic storm; and magnetic disturbance may arise with solar quiet—that is, the area of disturbance may be variable. Whatever may be the cause that extends or restricts the area, we obtain a knowledge of its extent unfortunately only by the Sun-spot on the one side, and by the magnetic disturbance and its accompaniments on the other side—phenomena both of which may be in part or degree of the nature of secondary effects.

Another circumstance deserves notice. Many magnetic storms commence with a very sharp movement of lesser or greater magnitude occurring simultaneously in all elements, declination, horizontal force, and vertical force, with accompanying earth current. This first movement may somewhat precede the magnetic disturbance or storm, or it may itself usher in the storm. In either case the distinctive characteristic is that the initial movement is sudden, sometimes sudden and large, and in the majority of cases at Greenwich is in the same direction, increasing the magnetic declination, horizontal force, and vertical force. And any marked or considerable initial movement becomes felt at the same absolute time—not nearly at the same time, but absolutely so, as nearly as the scale employed for photographic registration will allow of measurement—at places widely distributed over the earth's surface, each place having, as at Greenwich, its own distinctive characteristic as regards variation of the different magnetic elements. Magnetic disturbance having once set in, the following movements show similarity at places not far apart, but considerable dissimilarity at places widely separated; the first impulse however coming commonly after some period of magnetic quiet is found, as described, to be in a special degree simultaneous at different places. The Earth as a whole seems to feel an instantaneous shock, which would thus appear to be by action from without. (*Proc. Royal Society*, vol. 52, p. 191.)

As to the fluctuations that occur in magnetic storms, Sir George Airy, in a paper "First Analysis of 177 Magnetic Storms," communicated to the Royal Society in 1863, suggested that there may be something in proximity to the earth which he would call a magnetic ether, in which currents exist liable to interruptions or perversions that produce violent eddies and whirls, instancing the cyclonic and other phenomena of atmospheric storms and whirlpools in water; and Dr. Schmidt (*Terrestrial Magnetism*, vol. 5, p. 87), considering the diurnal magnetic variation to be referable to electric currents in the upper regions of the atmosphere, believes that the immediate cause of magnetic storms is to be referred to electric whirls or vortices which separate themselves from the general electric field in the atmosphere just as do the cyclones and anti-cyclones known to meteorologists, and he is led to conclude that for the greater part the

causes of our observed magnetic storms come from outside the earth's crust.

There is yet a phase of magnetic disturbance about which something may be said. Active magnetic disturbance and magnetic storms cluster principally, as we know, about periods of Sun-spot maximum, those about Sun-spot minimum being characterised by more or less prolonged magnetic quiet. But considering magnetic disturbance with reference to the year, it is found that at Greenwich there is also a seasonal variation. The number of days of magnetic disturbance during the period 1848 to 1897, classed in my paper (*Monthly Notices* for 1900 December) as being days of active and great disturbance, is 374, and their seasonal distribution, taking February, March, and April to represent spring, and May, June and July to represent summer, and so on, is as follows :—

Number of Days of Active and Great Magnetic Disturbances at Greenwich, 1848 to 1897.

Spring.	Summer.	Autumn.	Winter.
121	66	115	72

Near equinoxes 236.
Near solstices 138.

There is a certain irregularity in individual years, noteworthy disturbance appearing sometimes unusually early in the year, as in 1861 January, and sometimes unusually late, as in 1882 November; but in the aggregate of years it is seen that a distinct seasonal variation exists. A closer examination shows that the spring maximum appears, on the whole, to fall somewhat before the equinox, and the autumn maximum somewhat after the equinox, in the months of February and October respectively. Thus we have, superposed on the variation of magnetic disturbance with Sun-spot frequency, a seasonal variation with maxima at the equinoxes and minima at the solstices, showing that the earth or its near surroundings has a part in determining the form in which the external influence reaches us. The related physical circumstance is that at the equinoxes, when disturbance is more frequent, the whole surface of the earth comes under the influence of the sun, whilst at the solstices, when magnetic disturbance is less frequent, a portion of the surface remains for a considerable period in shadow.

Attention may be drawn also to the relation existing between magnetic disturbance and the aurora. In our latitude not only do both phenomena vary with Sun-spot frequency, but the aurora is at Greenwich subject to a like seasonal variation. Extracting from Mr. R. C. Mossman's paper on "The Aurora Borealis in London from 1707 to 1895" (*Journal of the Scottish Meteorological Society* for 1897), the number of days of aurora during the years

1848 to 1895, and combining the months as for magnetic disturbance, we find :—

Number of Days of Aurora in London, 1848 *to* 1895.

Spring.	Summer.	Autumn.	Winter.
57	14	63	43

Near equinoxes 120.
Near solstices 57.

Here is a seasonal variation similar to that in number of days of magnetic disturbance, and here also the spring and autumn maxima occur in the months of February and October respectively. In higher latitudes the seasonal variation of the aurora is different, showing the local terrestrial effect to be different at different places on the Earth's surface ; is it also different in the case of number of days of magnetic disturbance ?

Observations of the Sun during 1901 *May* 17, 18, *and* 20, *at Mells, near Frome,* 10 *miles due south of Bath.* By Maures Horner.

On several occasions I have tried to examine the edge of the solar surface before and after a total eclipse in order to ascertain whether the prominences and metallic eruptions, which are seen by means of the spectroscope at other times compare in size and shape with the phenomena of a total eclipse.

In May last there was an opportunity of observing the Sun while the total eclipse was actually in progress, but owing to the screen of east wind haze—so persistent all through the spring—it was impossible to get satisfactory results, although the sky was remarkably free from cirrus and cumulus. On Friday, the 17th, I sketched the contour fairly accurately, using on the 5-inch Cooke one prism of very dense Iena glass by Hilger, which gives almost perfect definition, and widely separates the sodium lines with a low power. The drawing shows little solar activity, the E.N.E. limb alone displaying a certain amount of disturbance, probably due to the collection of small spots which came into view on the 19th. Further south, on the same side, was a fairly large prominence, with the peculiarity of a curious patch of bright colour between the two points. The same elevated bright cloud appearance was also visible in the south-west quadrant west of two rather dim forms at about 200°, which were quite conspicuous whenever the haze became a little more transparent. On the north-west limb there was a long attenuated form and a bright spot at the exact west point. With these exceptions the Sun's limb was practically undisturbed.

The haze was bad enough at noon on Friday, and therefore at 5.30 on Saturday morning there was not much probability of any

useful observation. However, I got up and carefully examined the most likely places to the east north-east and south south-west. At the former, near 83°, there were two brightish forms leaning southwards, whilst at 200° the double prominence of the day before had taken a more pyramidal shape of rather distinct outline. On the extreme north limb the surface was exactly like short soft hairs, quite different from the south, where the surface was smooth, with a long, attenuated filament pointing to two small spots rising from the surface. Later in the morning, when the haze had cleared off somewhat, I tried for the so-called coronal line No. 1474, which was at first quite easily observed. It was very plain just below the east point at 100°, also above at 60°, less so at 40°, and then again west of the north point there seemed to be another extension about 340°, and from there until 300° it was fairly strong, but invisible after that either on account of the haze or else from real solar causes.

These observations were very disappointing, and the more so because the Sun was free from cloud. However, on Monday, the 20th, a sensational phenomenon deserves some record. After observing the small group of spots above referred to, I found a feeble prominence and managed to show it, not without a good ideal of difficulty, to a friend who had never seen one before. Then, continuing round the limb, we reached the north part, and found a bright prominence of a curiously rounded dome-like form. This my friend saw without the smallest difficulty. As it was close on noon, I turned away to explain the sidereal clock and set watches. We certainly did not leave the telescope for more than five minutes, but on examining the limb again I found that the prominence had totally disappeared. I have seen many wonderful changes, but never such a sudden extinction of a bright but apparently not very active eruption. There could be no doubt about it, as the north part is much the most easily observed portion of the solar limb.

Solar Eclipse 1901 *May* 18. By W. Ernest Cooke, Government Astronomer.

Partial phase observed at the Perth Observatory, Western Australia.

		h m s	
First contact	1901 May 17,	17 13 26·64	G.M.T.
Last ,,	,,	18 54 06·10	,,

Weather cloudy and showery, but Sun's limb was clear at both contacts, and observations considered good.

Perth Observatory, W.A.:
1901 *May* 18.

Estimations of Magnitude of Nova Aurigæ in 1899–1900, with the mean results for the years 1892–1900, from observations at the Radcliffe Observatory, Oxford.

(*Communicated by Arthur A. Rambaut, M.A., Sc.D., F.R.S., Radcliffe Observer.*)

The observations of *Nova Aurigæ* given in this paper are in continuation of those published in the *Monthly Notices*, vol. lix. p. 258. Estimations of the magnitude of this star have also appeared in vol. lii. pp. 430, 431; vol. liii. pp. 33, 34, 126; vol. lv. p. 164; vol. lvi. p. 234; and vol. lviii. p. 180.

A chart giving the approximate positions of the *Nova* and comparison stars will be found in vol. lii. p. 431. The letters denoting the comparison stars in this paper refer to this chart.

The estimations were made with the Barclay Equatorial of 10 inches aperture.

1899 April 1, $9\frac{1}{2}^h$.—*Nova* > $d=e=\xi$. Stars seen with difficulty; field bright with scattered light; slight condensation found on object-glass. Powers used, 80 and 100. (C.)

1899 April 10, 10^h.—*Nova* slightly brighter than ξ, d, and e by about 0·3 or 0·4 magnitude. Sky suddenly clouded over immediately after this observation. (R.)

1900 October 4, $10\frac{3}{4}^h$.—*Nova* fainter than any of the comparison stars of the chart except p, which it excelled in brightness by 0·3 magnitude. *Nova* seemed nebulous, with occasionally a stellar nucleus. Bright moonlight. With power 250 the following estimations of magnitude of *Nova* and comparison stars were made: $a=10{\cdot}5$; $b=11{\cdot}5$; $c=11{\cdot}7$; $\xi=12{\cdot}7$; $d=12{\cdot}7$; $e=13{\cdot}0$; $f=13{\cdot}2$; *Nova* $=13{\cdot}4$; $p=13{\cdot}7$. (R.)

1900 November 17, 10^h.—*Nova* seems to be about 0·2 or 0·3 brighter than on October 4. With power 250, the following estimations of magnitude of *Nova* and comparison stars were made: $a=10{\cdot}5$; $b=11{\cdot}5$; $c=11{\cdot}6$; d and $\xi=12{\cdot}6$; $e=13{\cdot}0$; *Nova* $=13{\cdot}2$; $f=13{\cdot}4$; $p=13{\cdot}7$. There is a wide companion to p nearly same magnitude (about 13·9), and this companion appears to be elongated. It is situated between a and p at about $\frac{1}{4}$ the distance from a to p. [Subsequently identified with M of Burnham's chart, *Monthly Notices*, vol. lii. facing p. 436.] (R.)

1900 December 13, 7^h.—*Nova* is fainter than any of the comparison stars in chart except f and p. *Nova* estimated as $=f$ and $> p$. (R.)

Adopting for the comparison stars the magnitudes given in vol. lii. p. 431, we have for the magnitude of *Nova Aurigæ*:

1899		h		
April	1,	$9\frac{1}{2}$	13·5	Observer C.
	10,	10	13·3	„ R.
1900		h		
Oct.	4,	$10\frac{3}{4}$	14·1	„ R.
Nov.	17,	10	13·9	„ R.
Dec.	13,	7	13·8	„ R.

Observers: R. Mr. Robinson.
C. Mr. McClellan.

The mean magnitudes from 1892 to 1900 are:

1892	4·5 to < 14·0	Feb. 3 to March 31
„	9·5 to 9·8	Sept. 8 to end of year
1893	9·7	
1894	9·7	
1895	9·7	
1896	...	
1897	11·4	
1898	12·0	
1899	13·4	
1900	13·9	

Radcliffe Observatory, Oxford:
1901 *June* 13.

Further Observations of the New Star in Perseus made at the Radcliffe Observatory, Oxford.

(*Communicated by Arthur A. Rambaut, M.A., Sc.D., F.R.S., Radcliffe Observer.*)

This paper contains the results of observations upon the brightness and colour of the new star in *Perseus* made at the Radcliffe Observatory since the date of the last meeting of the Society, and is in continuation of the Notes, on the same subject, already communicated to the Society and published in the *Monthly Notices* for March, April, and May.

With the exception of two observations made by Mr. Robinson on May 12 and 14, all the estimations were made with

telescopic aid. After May 18 the star could no longer be followed with the Barclay Equatorial, and accordingly from that date most of the observations were made with the 7½-inch Heliometer.

The observations were for the most part difficult owing to the amount of twilight and the low altitude of the star. Between May 11 and 24 the sky was generally very clear, and an almost continuous series of observations was obtained.

The observations this month continue to indicate the relationship already pointed out between the colour and magnitude of the star, on the whole the redness of the star increasing as the brightness is diminished.

The light period continues to show considerable fluctuations. Between May 11 and 24 there are two periods of four or five days followed by a three days' period.

The amplitude of the oscillation in brightness appears to be about 1½ magnitudes, as before; while the mean magnitude about which it oscillates has remained unaltered since April 20.

Table I.

List of Stars used for Comparison with Nova Persei.

Ref. No.	Name of Star.	Harvard Photom. Mag.	Ref. No.	Name of Star.	Harvard Photom. Mag.
40	κ Persei	3·95	53	36 Persei	5·40
42	ν Persei	4·00	54	Arg. Z. + 44°, 734	6·04
48	σ Persei	4·39	55	Arg. Z. + 44°, 648	6·47
50	l Persei	4·84	56	Arg. Z. + 43°, 818	5·97
52	30 Persei	5·37	59	Arg. Z. + 42°, 795	6·30*

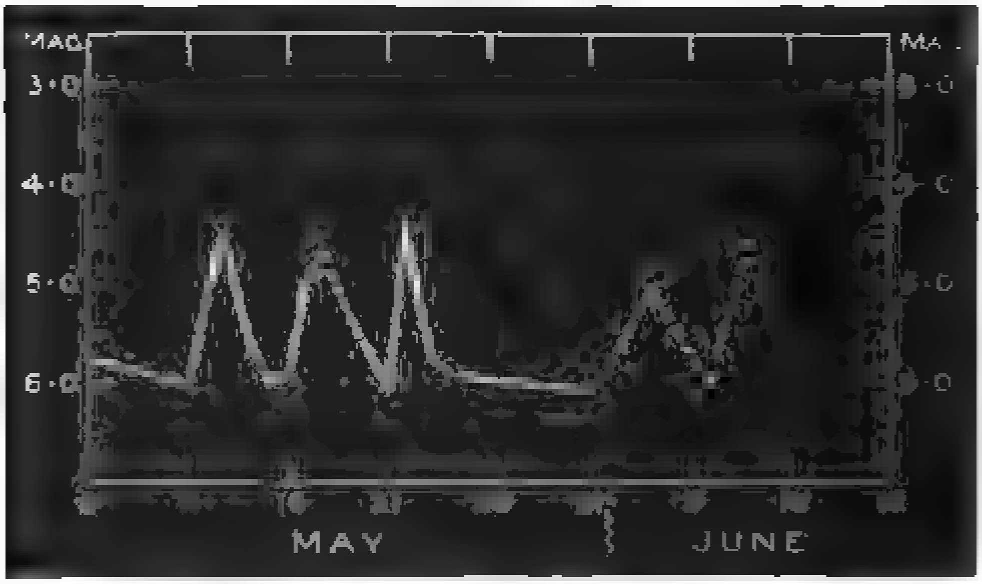
* Harvard Photom. D.M.

Table II.

Means of Estimations of Magnitude of Nova Persei.

G.M.T.			Observer.	Reference Stars.	Mean Mag.	Adopted Mag. for the Night.
1901.	h	m				
May 11	9	0	R.	56	6·10	6·05
	9	5	C.	56	6·00	
12	9	53	W.	52, 50, 55, 56, 53	5·36	5·20
	10	0	C.	50, 52	5·05	
	10	5	R.	50	5·00	
13	8	35	R.	50, 42	4·40	4·50
	10	0	W.	50, 48, 40	4·60	
14	9	53	C.	52, 56	5·55	5·55
	10	0	R.	50	(5·1)	
15	8	30	R.	52, 56	6·00	6·00

G.M.T. 1901.	h	m	Observer.	Reference Stars.	Mean Mag.	Adopted Mag. for the Night.
May 16	10	0	C.	52, 56	5·90	5·90
	10	15	R.	56, 52	5·90	
17	10	15	R.	52, 56	5·00	5·00
18	8	20	R.	42	4·80	4·65
	10	0	C.	50	4·50	
20	9	45	C.	52, 56	5·70	5·67
	9	47	R.	52, 56	5·60	
	9	47	R.	52, 56	5·70	
21	9	53	C.	52, 56	6·05	6·05
22	11	5	R.	42, 50, 40	4·40	4·40
23	9	45	R.	52, 56	5·70	5·70
24	9	45	R.	52, 56, 54, 59	5·88	5·88
31	9	45	R.	54, 56	6·10	6·10
June 3	11	0	R.	50, 52	5·05	5·05
6	10	30	R.	54, 56	6·00	6·00
8	11	0	R.	52, 50, 42, 40	4·57	4·57



Magnitudes of Nova Persei.

Observers' Notes on the Estimations of Magnitude.

1901.

May 12. No. 52 not visible to the naked eye, except perhaps momentarily. Sky very clear, but objects low. Twilight rather strong. (R.)

May 13. Very difficult; strong twilight. (R.) Half-weight to No. 48; this star is much higher than Nova. (W.) Could not see the Nova with the naked eye at 10ʰ; Nos. 40 and 42 were only occasionally visible through haze. (R.)

1901.

May 14. Observed with Marlborough, power 80. Nos. 50 and 52 were also easily visible in the "finder," but the Nova was only seen with some difficulty. Sky clear. (C.) Suspected a glimpse of the Nova with the naked eye at 10^h, when I estimated it to be fainter than No. 50 by 0·3. This observation is doubtful, but the Nova was certainly not brighter than magnitude 5. Sky very clear. (R.)

May 16. Observed with Marlborough, power 80. In "finder" Nova and No. 56 were equally difficult to pick up, but Nos. 52 and 50 were easily seen. (C.)

May 17. Sky hazy and cloudy; observations very difficult.

May 18. Twilight strong, and haze prevalent low down. Observation only approximate. (R.) Sky hazy; very difficult estimation. (C.)

May 20. Sky clear. (C.) The first observation by R. was taken with the Heliometer 7·5-inch; the second with the 1·83-inch "finder."

May 21. Sky very clear; many small stars visible near.

May 22. Observed near lower culmination. Altitude 5°.

May 23. In the 7·5-inch (Heliometer) the image of the Nova was equal in size, but inferior in brightness to No. 52. Sky very clear.

May 24. Sky very clear. A star (Arg. Z. + 42°, 803) follows No. 59 by 1^m, and is south. It is fainter than No. 59 by 0·5 mag.

May 31. Flickering images.

June 3. Images good at times; objects low.

June 8. Observed near meridian (sub polo). No. 40 is more than a magnitude brighter than 42, which is 3° lower in the haze. The magnitude estimations are sensibly confirmed by observer C. with the same telescope.

Observers' Remarks on Colour of Nova and Comparison Stars.

1901.

May 11. With the 10-inch Barclay and power 45 Nova is orange with very red fringe. (R.) Very red in 10-inch. Sky very hazy. Atmospheric conditions similar to those at time of sunset, when Sun was of a deep orange tint. (C.)

May 12. Exceptionally clear. Nova's colour in the 1⅞-inch is a much fainter red than I have seen for more than a month. The stars were very low, and No. 14 exhibited rapidly changing colours of the spectrum. Images generally very good. (W.)

May 13. Sky is not nearly so clear as last night; there is an absence of red tint from Nova; I could detect none in the 1⅞-inch. The observations are a little doubtful owing to small altitude. (W.) Nova in the Barclay has a large central yellow disc with small but bright red wings. No. 42 is yellowish this evening. (R.)

May 15. Redness of Nova in the Barclay becomes more apparent as the twilight wanes.

May 16. Nova very red in Marlborough. (C.) Nova red in Marlborough. (R.)

May 20. Nova very red in Marlborough. (C.) Contrast in colours of Nova and comparison stars with the Heliometer. Nova red. (R.)

May 21. Nova red in Marlborough.

May 22. Nova red in Heliometer, and No. 40 reddish-yellow. Objects low.

May 23 and 24. Nova red in Heliometer.

June 6. Nova not very red in Heliometer. Objects low.

June 8. Nova and No. 40 red in Heliometer. Low in haze.

The observers were:

Mr. Wickham, indicated by W.
Mr. Robinson, „ „ R.
Mr. McClellan, „ „ C.

Radcliffe Observatory, Oxford:
1901 *June* 13.

Observations of Nova Persei made at Birr Castle Observatory, Parsonstown. By the Earl of Rosse, F.R.S.

During the time that *Nova Persei* was visible every opportunity was taken for observing that interesting object, but I happened to be in England at the time and no authentic information as to its existence reached us until after its maximum brightness had been much reduced, and subsequently the extreme uncertainty of weather which prevailed at that time much impeded observations. For that reason, however, the work of others was also fragmentary, and in the hope of filling gaps rather than of adding any important matter the notes made at the time from observations principally by Dr. Boeddicker are sent in. Spectroscropic observations were not satisfactory, the instruments having lain unused for some years and having deteriorated with time.

With a direct-vision prism, however, placed between the eye and the eyepiece of the 3-foot reflector, the red line was quite unmistakable. Others in the more refrangible regions were at times satisfactorily seen, but it was not always easy with the means at our disposal to distinguish between a bright line and an absence of dark lines in a continuous spectrum.

Through the whole time that the star was visible the prevailing easterly wind and the accompanying thin clouds generally diffused the star's light and destroyed definition of prism used without a slit. No photography was attempted.

1901 March 1, 10^h M. T. Greenwich. A hurried estimate between clouds. *α Persei* $\geq$ *Nova.*

1901 March 2, 10^h to $10^h\ 50^m$. Sky bad. Passing clouds and haze. Examination during bright interval. *α Persei* > *Nova. Nova* distinctly red. With direct-vision spectroscope before eyepiece, the red very intense at its extreme end, cut off from yellow by very decided dark bands or lines. Further dark lines, very conspicuous, in blue, also—but fainter, ~~more suspected~~ —in violet.

1901 March 3. Passing clouds. *α Persei* > *Nova*; no perceptible change in magnitude since last night. Spectrum magnificently seen with cylindrical lens. Very bright line in red, separated from yellow by a broad, dark band (darkest towards red). Faint narrow dark line in orange, also one between yellow and green. Green fairly uniform, very intense and well defined towards blue, where it is abruptly cut off by a broad dark band. This is followed by a sharply defined bright band (or are there two?) in blue. Very dark band between

blue and violet. A bright band at times suspected in extreme violet.

1901 March 6. Storm and rain. One glimpse of *Nova.* Magnitude 3.

1901 March 7. Fairly clear. Well seen. Magnitude below 3. Extreme red very intense, terminated by a dark band towards yellow. Bright line in yellow. Dark bands in bluish green and blue. A brighter band in blue towards violet. Dark lines in violet suspected.

1901 March 8. Magnitude 4. Intensely red line followed by very dark absorption band. Dark band in green followed by a bright band. Very dark bands in blue. Bright band in blue towards violet (or are there dark absorption bands in violet towards the blue ?). Violet seems of uneven brightness; there is decidedly a brighter part or band in its extreme end. Dark bands or lines (in violet) suspected.

1901 March 13. Sky very bad. Hazy. Magnitude below 4. Spectrum very badly seen owing to haze and thin clouds.

1901 March 14, $9^h 40^m$. Sky very hazy, stars very dim. *Nova* nearly $=o$, certainly $>r$. Magnitude increased to about 3·3. Extremely bright line in red followed by dark absorption bands. Dark lines in green, leaving central portion bright, looking like a bright band. Very conspicuous bright line in blue-green, also faint indication of a bright band in violet.

1901 March 21. Sky hazy. Images bad and unsteady. *Nova* fainter than ν but slightly brighter than κ. Red line very conspicuous, followed by very dark absorption band up to yellow. Dark lines suspected in green. Bright band in bluish green very striking, bright band in extreme violet unmistakable.

1901 March 22. Sky hazy. Images unsteady. 5th magnitude stars only visible with great difficulty. *Nova* below σ or 4·5 mag.; almost 5.

1901 March 25. Clear, cold. ☾. *Nova* almost 6th mag.

1901 April 8. Sky very bad. Covered with cirro-s. Cleared somewhat at $11^h 40^m$; when low near the horizon the *Nova* became visible, having increased again to about 4·3 mag., *i.e.* ·2 or ·3 mag. below κ. Not to be reached with telescope.

1901 April 9. Clear for a short time. *Nova* out of reach with 3-foot reflector; viewed with 4-inch refractor. Magnitude about 4·5, perhaps somewhat brighter. Slightly below κ, yet it

appeared as if this inferiority was due to the difference of colour. At times both equally well seen. Spectrum very striking and hardly, if at all, different since former observation. Very strongly pronounced red line. Bright band suspected in yellow. One, perhaps two, seen in green.

1901 April 10. Sky partly clear. *Nova* much decreased in brightness, below 32 *Persei*. Just on the verge of visibility with naked eye; only to be seen in glimpses.

1901 April 11. Partly clear at first, then cloudy. *Nova* not very much fainter than last night. Still visible in glimpses, yet with less certainty. Magnitude decidedly below 6.

Further Observations of the New Star in Perseus (4). By A. Stanley Williams.

During the month of May the position of *Nova Persei* was very unfavourable, and the observations were necessarily made with the star at a low altitude and on a bright sky. Notwithstanding, however, these unfavourable conditions, the estimates of the brightness of the *Nova* have been mostly quite satisfactory owing to fine weather and the generally clear sky even at a very low altitude.

The following estimates of the brightness of the new star were all made with a power of 35 on the $2\frac{3}{4}$-inch refractor; and in no case, it may be mentioned, was there any uncertainty with regard to the identity of the object or of the comparison stars. No correction for difference of atmospheric absorption has been applied to the provisional magnitudes in the last column, although this correction would probably be quite sensible in the case of the evening observations, at any rate as regards the comparisons with 36 *Persei*. It is probable, therefore, that the provisional magnitudes from the evening observations may be slightly too low, though the influence of the peculiar colour of the star in possibly modifying the effects of absorption perhaps requires to be taken into consideration. In the morning observations the *Nova* and the two comparison stars 36 *Persei* and *a* (B.D. $+44°$, 734) were all nearly at the same altitude, and should have been about equally affected by absorption. In some cases, where comparisons were made in the evening at short intervals, the separate results are given, as they may be of assistance with regard to this question of absorption. The progressive diminution in brightness shown by the last three observations of May 22 may well have been due to the effect of increased absorption as the star approached the horizon. On May 23 we have a similar change.

Date. 1901.	G.M.T. h m	Observations.	Provisional Magnitude.
May 12	9 50	Nova = $a-2$ ($b-12$)	6·3
13	9 19	36 Persei + 0·3, $a-11$	5·4
14	9 21	36 Persei + 8, $a-2·7$	6·2
15	9 30	$a+1$ ($b-9$)	6·6
17	9 10	36 Persei + 4, $a-7$	5·8
	9 45	36 Persei + 5, $a-6$	5·9
18	9 30	36 Persei + 4, $a-7$	5·8
	9 50	36 Persei + 5, $a-6$	5·9
20	9 10	36 Persei + 8, $a-3$	6·2
	9 25	36 Persei + 9, $a-2$, $b-9$	6·2
	9 35	36 Persei + 11, $=a$, $b-9$	6·3
21	9 15	36 Persei + 9, $a-2$	6·3
	9 25	36 Persei + 10, $a-2$, $b-9$	6·2
	9 30	36 Persei + 11, $a-1$, $b-9$	6·3
	9 40	36 Persei + 10, $=a$, $b-10$	6·3
22	9 20	36 Persei + 1, $a-11$	5·45
	9 35	36 Persei − 5	4·9
	9 40	36 Persei − 4	5·0
	9 45	36 Persei − 2	5·2
23	9 20	36 Persei + 6, $a-5$	6·0
	9 36	36 Persei + 9, $a-3$	6·25
	9 40	36 Persei + 9, $a-2$	6·3
24	9 30	$a-5$	6·0
	9 35	36 Persei + 8, $a-3$	6·2
	9 36	36 Persei + 8, $a-3$	6·2
	9 38	36 Persei + 8, $a-3$	6·2
June 6	13 50	36 Persei + 8·7, $a-5·7$	6·1
8	13 46	36 Persei − 1 ($a-15$)	5·3
10	14 19	36 Persei + 12·5, $a-2$	6·45

Notes.

May 12, very clear. May 13, very clear; mean of 3 observations between $9^h\ 8^m$ and $9^h\ 30^m$. May 14, exceedingly clear; mean of 3 observations between $9^h\ 10^m$ and $9^h\ 35^m$. May 15, not very clear. May 17, clear intervals between clouds. May 18, a little hazy. May 20 and 21, very clear. May 22, very clear; star too bright for proper comparison with a. May 23, very clear. May 24, considerable thin cirrus cloud about, but a narrow strip of sky just above the horizon seemed perfectly clear, and it is believed the estimates were not affected by the cloud. June 6, hazy; mean of 3 observations between $13^h\ 40^m$ and $14^h\ 0^m$. June 8, very clear; mean of 3 observations between $13^h\ 5^m$ and $14^h\ 17^m$. June 10, considerable thin cloud, but the observations were certainly not affected by this; mean of 4 sets of comparisons between $14^h\ 7^m$ and $14^h\ 30^m$. The star designated b is BD. + 43°, 730.

Although the fluctuations in brightness have continued, the star does not seem to have varied to the same extent as formerly. The observations show that the star was more or less bright on the following dates: May 13, 17–18 (slight), 22, and June 8. Apart from these temporary or periodical fluctuations, the *Nova* seems to have remained almost stationary during the past month.

Observations of colour have been practically impossible lately owing to the low altitude, but on May 13 the star seemed strongly reddish, and on May 14 it was noted as being evidently a very deep red. On May 22, when the star was bright, it appeared as a flaming bright star of a pronounced red colour, even at $9^h\ 45^m$, when the altitude was very low. On June 8, at $13^h\ 55^m$, the colour seemed to be orange.

1901 June 12.

Secular Variation in the Period of R Carinæ.
By Alexander W. Roberts, D.Sc.

The periods of several of the Southern Long Period Variables seem subject to secular variation, but with the exception of *R Carinæ* the observations are either too discontinuous or too meagre to afford even a remote idea of the amount and nature of the variation.

With regard to *R Carinæ* sufficient observations have, I think, accumulated during the past twenty years to indicate the salient characteristics of the irregularities which affect its variation.

The first observation of which we have any record is that made by Lacaille on 1752 March 3. As Lacaille estimated it as of the seventh magnitude, it could not then have been far from its maximum brightness. This observation is therefore of importance as fixing within certain limits the period of the variable.

In 1867 two meridian observations of *R Carinæ* were made very near a maximum phase by Ellery at Melbourne.

The two observations are :—

1867 March 31	... ...	Magnitude 6·5
„ April 3	... ...	„ 6·0

This, taking the average rate and extent of variation of *R Carinæ*, would mean a maximum on or about 1867 April 25.

The observations made by Brisbane and Stone are not of value in any investigation dealing with the light changes of *R Carinæ*, as position rather than brightness was the purpose of their observations. It is indeed possible that Stone simply copied Lacaille's magnitude into his observation book.

The discovery of the variation of *R Carinæ* was made by Gould in 1871, and during this and the following three years continuous observations were made of it at Cordoba.

These yielded (*Uranometria Argentina*, p. 251) the following four maxima dates :—

1871 July 17	... ...	Julian Day	2404626
1872 June 10	... ...	„	2404955
1873 April 12	... ...	„	2405261
1874 March 4	... ...	„	2405587

The long and highly valuable series of observations made by Tebbutt, at Windsor, New South Wales, was begun in 1880. Without these earlier observations by this indefatigable worker, an investigation of the secular inequalities of *R Carinæ* would not, I think, be possible at the present date.

In 1891 regular observations were begun at Lovedale, and have been carried on until now with only one short interval. We have accordingly continuous observations of *R Carinæ* for over twenty years. If we include Gould's observations the series extends, with one break, over thirty years.

The following list gives the various maxima which have been determined, beginning with the estimated maximum of 1867 (Melbourne).

Rotation No.	Maximum.	Julian Day.	Observed at.
1	1867 April 25	2403082	Melbourne
2	1871 July 17	2404626	Cordoba
3	1872 June 10	2404955	„
4	1873 April 12	2405261	„
5	1874 March 4	2405587	„
6	1880 Dec. 16	2408066	Windsor
7	1881 Oct. 21	2408375	„
8	1882 Aug. 30	2408688	„
9	1883 July 6	2408998	„
10	1884 May 24	2409321	„
11	1885 April 5	2409637	„
12	1886 Jan. 27	2409934	„
13	— Dec. 8	2410249	„
14	1887 Oct. 13	2410558	„
15	1889 June 23	2411177	„
16	1890 April 13	2411471	„
17	1892 Jan. 1	2412099	Lovedale
18	— Nov. 3	2412406	„
19	1893 Aug. 25	2412701	„
20	1894 July 2	2413012	„
21	1895 May 11	2413325	„
22	1898 Sept. 15	2414548	„
23	1899 July 12	2414848	„
24	1900 May 17	2415157	„
25	1901 March 20	2415465	„

As already stated, the observation made by Lacaille is of importance as indicating between what limits the mean value of the period of *R Carinæ* must lie. Lacaille's observation was

made on 1752 March 3, the magnitude on that date being 7·0. Now either *R Carinæ* was then rising to its maximum brightness or it had already passed it. An examination of the mean light curve indicates that *R Carinæ* passes what is apparently Lacaille's seventh magnitude standard 50 days before maximum or about 80 days after it. That is, in 1752 the maximum of *R Carinæ* took place either about January 23 or about May 22. The former date when related to recent maxima yields a period of 309·7 days, and the latter date 309·0 days. Between these two values the mean period of *R Carinæ* must lie.

In a recent catalogue of Southern Variable Stars (*Astronomical Journal*, vol. xxi. p. 85) I considered the former of the two values, 309·7 days, as the one which most closely corresponds with observation. With this period as a known quantity, the full elements of variation are :—

$$\text{(I.)} \quad M = 2415180 + 309^{d}\cdot 7\,E + 25^{d} \cos (10^{\circ}\,E - 180^{\circ})$$

That is, a full cycle of the inequalities affecting the period of *R Carinæ* is completed in about thirty-one years.

With these elements the maximum dates given in column 4 have been computed. Column 5 gives the residuals between the dates so computed and the observed dates (column 3).

Rotation No.	E	Observed Max. J.D.	I. Computed Max. J.D.	O–C	II. Computed Max. J.D.	O–C
				d		d
1	−39	2403082	2403080·1	+ 1·9	2403086·5	− 4·5
2	34	2404626	2404626·8	− 0·8	2404636·5	−10·5
3	33	2404955	2404938·3	+16·7	2404947·7	+ 7·3
4	32	2405261	2405250·4	+10·6	2405259·3	+ 1·7
5	31	2405587	2405563·2	+23·8	2405571·3	+15·7
6	23	2408066	2408073·0	− 7·0	2408070·5	− 4·5
7	22	2408375	2408385·8	−10·8	2408382·5	− 7·5
8	21	2408688	2408697·9	− 9·9	2408694·1	− 6·1
9	20	2408998	2409009·4	−11·4	2409005·3	− 7·3
10	19	2409321	2409320·3	+ 0·7	2409316·2	+ 4·8
11	18	2409637	2409630·4	+ 6·6	2409626·7	+10·3
12	17	2409934	2409939·7	− 5·7	2409936·7	− 2·7
13	16	2410249	2410248·2	+ 0·8	2410246·2	+ 2·8
14	15	2410558	2410556·1	+ 1·9	2410555·3	+ 2·7
15	13	2411177	2411170·0	+ 7·0	2411172·0	+ 5·0
16	12	2411471	2411476·1	− 5·1	2411479·7	− 8·7
17	10	2412099	2412087·3	+11·7	2412094·1	+ 4·9
18	9	2412406	2412392·7	+13·3	2412400·7	+ 5·3
19	8	2412701	2412698·7	+ 2·3	2412707·1	− 6·1
20	7	2413012	2413003·5	+ 8·5	2413013·4	− 1·4
21	6	2413325	2413309·3	+15·7	2413319·5	+ 5·5
22	2	2414548	2414537·2	+10·8	2414543·9	+ 4·1
23	1	2414848	2414845·7	+ 2·3	2414750·3	− 2·3
24	0	2415157	2415155·0	+ 2·0	2415156·9	+ 0·1
25	+1	2415465	2415465·1	− 0·1	2415463·9	+ 1·1

To determine if any correction to the elements of variation :—

$$\text{(I.)}\quad M=2415180+309^{d}\cdot7\,E+25^{d}\cos(10^{\circ}\,E-180^{\circ})$$

would better satisfy the recorded observations, differential equations were formed from the above elements, and these being solved gave a system of corrections. Once more with the corrected elements a new set of differential equations was formed, and these gave as a final result :—

$$\text{(II.)}\quad M=2415172+309^{d}\cdot3\,E+23^{d}\cos(8^{\circ}\cdot2\,E-229\cdot1^{\circ})$$

The dates of maximum phase computed from these elements are given in column 6 of the preceding table, and the residuals in column 7.

The average residual computed from elements I. is

7·5 days ;

and the average residual computed from elements II.

5·3 days.

In order to exhibit the systematic variation in the duration of the period of *R Carinæ* in a more evident form, Plate 17 represents the discordances between observed and computed dates when the systematic correction

$$23^{d}\cos(8^{\circ}\cdot2\,E-229^{\circ}\cdot1)$$

is left out of account. The dotted curve in the figure is this systematic correction.

In this connection, however, it may be as well, in case of misapprehension, to point out that we have no certain assurance, and cannot have any for many years to come, that an expression of the form

$$a\cos(\theta E-M)$$

describes the secular irregularities affecting the period of *R Carinæ*.

It is assumed that the irregularities are of this nature, but until a full cycle is completed the assumption must have the character of an empirical explanation.

If we select a period of 309·7 days, one of the limits, it will be found that the residuals, when graphically represented, may be expressed under the form

$$a\cos(\theta E-M)+\beta\cos(2\theta E-N)\ ;$$

and this curve will as readily satisfy the discordances as the former.

Every year is, however, making a definite solution more possible, and in ten more years there will be sufficient data to

determine rigorously the amplitude and duration of the cycle of inequalities.

Meantime the curve given in Plate 17, and the elements set forth in Equation II., may be taken as generally descriptive of these inequalities, and any further and more refined consideration of fuller material will not materially alter the conclusions come to.

Put generally the conclusions are as follows :—

(1) The mean period of *R Carinæ* is 309·3 days, but this value varies from 305·8 days as one limit, to 312·8 days as the maximum limit.

(2) The lower limit was passed in 1896, and the maximum limit in 1877.

(3) At present (1901) the duration of the period is 307·4 days and is increasing.

(4) A full cycle of periodic inequalities is completed in 37 or 38 years.

One is tempted to wander into speculation as to the cause, or causes, of this anomaly; but until we know more about the conditions of motion, or about the chemical changes, or about both combined, that produce the type of long period variation that we find in stars of the same class as *R Carinæ*, such excursions are unprofitable.

I think, however, the solution of the problem would be advanced materially if at each recurring maximum careful measures were made of the motion in the line of sight of the brighter variables. It could then be determined if this long period inequality is in any way connected with orbital movement.

Lovedale, South Africa:
1901 *May* 9.

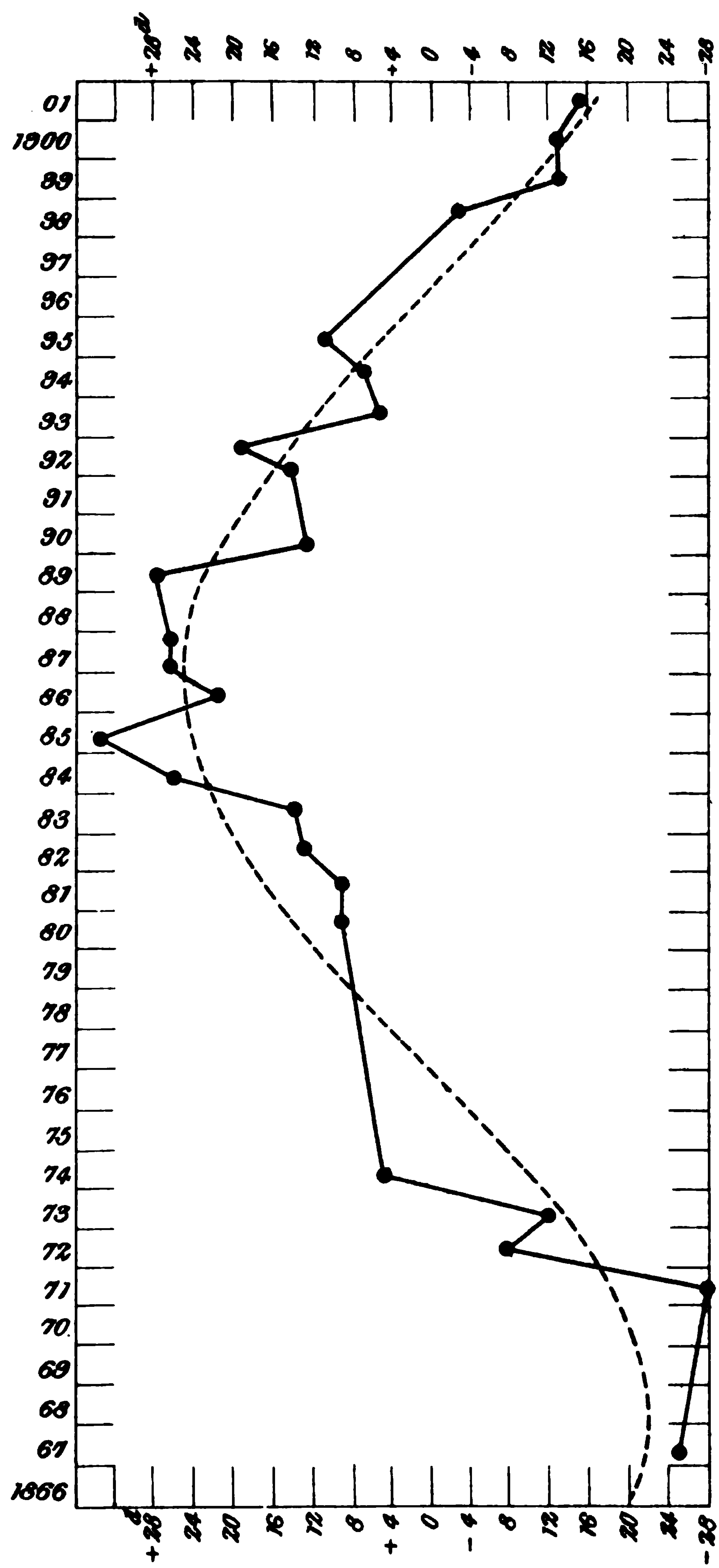
Measures of Double Stars made at Mr. Edward Crossley's Observatory, Bermerside, Halifax. By Joseph Gledhill.

The following measures of a selected list of important binary stars have been made with the Cooke Equatorial and Simms' Micrometer. Up to 1896 the object-glass was the 9⅓-inch Cooke; since that year a 9-inch photo-visual object-glass by the same makers has been used. The power most used was 290; occasionally 480 was used with advantage.

The usual method of measurement with a parallel-wire micrometer was followed.

Distances are almost always difficult to measure here owing to the unsteady air; hence it is that most of the distances under 1″ recorded below are rather careful estimations than measures. Very few years afford half a dozen nights good enough for measures of distances under 1″.

The R.A. and dec. are for 1900. When two or more sets of measures have been made in one year the mean value is given.



Secular inequality in the period of R Carinae.

Name.	R.A.	Dec.	Date.	Position Angle.	Distance.	Nights.
	h m	° ′		°	″	
Σ 3062 ...	0 1	+57 53	1895·282	330·6	1·3	1
			8·695	339·6	1·4	4
η Cass. Σ 60	0 43	+57 18	1891·059	190·8	4·7	4
			2·245	194·6	4·8	4
			3·218	198·8	4·7	4
			4·084	202·3	4·9	5
			6·545	209·9	4·8	5
			8·795	214·6	4·5	5
			1900·787	222·7	5·0	10
36 Androm. Σ 73	0 49	+23 4	1894·037	12·4	1·0	3
			6·896	15·6	1·3	3
			1900·786	17·0	1·0	8
γ^2 Androm. OΣ 38	1 58	+41 51	1896·833	117·6	0·5	5
			8·742	115·4	0·5	13
			9·561	115·4	0·5	4
14 *i* Orionis OΣ 98	5 2	+ 8 22	1891·079	189·9	1·1	2
			4·136	186·5	0·9	7
			6·108	183·7	1·0	4
			8·885	182·1	0·9	3
			9·033	180·7	...	1
η Orionis ...	5 19	− 2 29	1891·082	84·2	1·2	2
			2·451	84·1	1·1	8
			4·128	84·4	1·0	8
			6·154	86·5	...	5
			8·953	86·2	...	1
			9·024	81·1	1·0	6
12 Lyncis, A.B. Σ 948	6 37	+59 34	1891·075	122·3	1·8	2
			2·745	123·3	1·6	3
			1900·199	120·3	2·0	3
Castor Σ 1110	7 28	+32 7	1890·358	229·8	5·5	6
			1·107	230·0	5·6	10
			2·209	229·7	6·0	11
			3·272	228·1	5·7	10
			4·082	233·1	5·8	3
			5·281	227·7	5·6	5
			8·944	226·0	5·5	5
			9·177	225·1	5·8	19
			1900·492	225·7	5·6	16

Name.	R.A.	Dec.	Date.	Position Angle.	Distance.	Nights.
	h m	° ′		°	″	
ζ Cancri, A.B. Σ 1196	8 6	+17 58	1891·131	33·0	1·1	5
			2·419	27·2	1·0	6
			3·220	28·2	1·0	6
			4·060	23·3	1·0	4
			5·287	21·5	1·0	4
			6·265	18·2	1·1	6
			9·086	11·1	1·0	5
			1900·295	5·8	1·0	4
ω Leonis Σ 1356	9 23	+9 30	1890·252	102·1	0·7	5
			1·239	103·6	0·6	14
			2·244	103·5	0·7	9
			3·283	104·3	0·7	15
			4·093	104·4	0·8	7
			6·143	109·5	0·8	9
			7·360	107·0	0·8	6
			9·178	111·1	0·9	14
			1900·268	111·2	0·9	12
γ Leonis Σ 1424	10 14	+20 21	1890·251	114·1	3·7	5
			1·174	113·6	3·8	5
			2·255	112·9	4·1	10
			3·220	114·7	3·5	6
			4·131	116·3	3·7	5
			6·213	116·8	3·6	13
			7·360	114·7	3·7	6
			8·945	117·0	...	1
			9·194	116·4	3·9	16
			1900·266	116·3	3·6	11
ξ Ursæ Majoris Σ 1523	11 13	+32 6	1890·249	211·8	1·7	4
			1·273	201·0	1·3	18
			2·296	192·7	1·8	15
			3·301	184·7	1·7	17
			4·205	180·9	1·8	14
			6·272	173·9	2·0	7
			9·234	152·9	2·1	9
			1900·300	151·0	2·1	15
ι Leonis ... Σ 1536	11 19	+11 5	1897·257	55·9	2·4	1
			1900·317	57·0	2·2	3

Name.	R.A.	Dec.	Date.	Position Angle.	Distance.	Nights.
	h m	° ′		°	″	
γ Virginis ... Σ 1670	12 37	− 0 54	1890·246	153·4	5·5	3
			1·304	153·1	5·6	11
			2·336	151·8	5·8	11
			3·291	151·6	5·7	16
			4·247	151·3	5·5	9
			5·261	331·8	5·6	3
			6·266	332·3	5·7	6
			7·363	331·4	5·7	8
			1900·271	331·1	5·6	10
35 Comæ Ber. Σ 1687	12 48	+21 48	1895·501	75·6	1·0	4
			1900·313	77·0	1·1	2
25 Canum V. ... Σ 1768	13 33	+36 48	1895·501	137·2	1·0	4
			8·517	132·2	1·0	1
			1900·313	129·9	1·2	2
ξ Boötis ... Σ 1888	14 47	+19 37	1893·381	236·9	3·1	5
			4·346	232·7	3·1	4
			5·500	227·0	3·2	4
			7·531	216·7	2·5	1
			8·657	210·5	2·4	9
η Cor. Bor. ... Σ 1937	15 19	+30 39	1891·312	216·8	...	10
			2·489	234·?	...	12
			3·499	240·1	0·5	11
			4·295	261·7	0·4	3
			5·589	285·1	0·4	4
			1897·520	328·3	0·5	14
			8·517	343·4	0·5	1
			1900·382	5·5	0·7	6
μ² Boötis ... Σ 1938	15 21	+37 43	1892·392	94·1	0·8	4
			3·674	85·4	0·6	1
			4·297	85·9	0·9	2
			7·535	79·3	0·9	4
			8·657	77·3	0·9	10
γ Cor. Bor. ... Σ 1967	15 39	+26 37	1891·313	120·2	0·5	11
			2·567	120·0	...	4
			3·630	119·5	0·6	9
			4·321	118·6	0·7	3
			5·419	117·4	0·5	1
			7·513	116·7	0·7	12
			8·517	115·2	0·7	1
			1900·415	116·1	...	3

Name.		R.A.	Dec.	Date.	Position Angle.	Distance.	Nights.
		h m	° ′		°	″	
σ Cor. Bor. Σ 2032	...	16 11	+34 7	1892·560	206·7	4·0	2
				3·455	209·6	4·2	1
				4·328	210·3	4·0	3
				5·500	211·9	4·4	4
				7·509	208·8	4·3	14
				8·517	209·6	4·1	1
				1900·350	212·7	4·4	7
λ Ophiuchi Σ 2055	...	16 26	+ 2 12	1891·359	47·3	1·4	1
				2·693	47·5	1·5	2
				3·463	48·8	1·4	10
				7·545	49·3	1·3	4
ζ Herculis Σ 2084	...	16 38	+31 47	1893·449	54·4	1·4	4
				5·631	29·8	0·9	2
				7·543	16·1	0·7	4
				8·625	352·4	0·5	6
				1900·420	263	...	2
70 Ophiuchi Σ 2272	...	18 0	+ 2 33	1892·686	317·8	2·3	2
				3·449	311·8	2·4	8
				5·597	296·6	2·2	1
				6·887	289·7	2·0	3
				7·550	283·4	2·0	6
ε Lyræ Σ 2382	...	18 41	+39 32	1900·522	12·5	3·4	9
5 Lyræ Σ 2383	...	18 41	+39 31	1900·522	130·5	2·5	9
δ Cygni Σ 2579	...	19 42	+44 53	1890·715	310·7	1·4	4
				2·705	308·3	1·5	8
				3·613	305·6	1·6	20
				5·714	307·2	1·6	3
				6·871	304·5	1·7	5
				7·622	303·7	1·7	9
				8·676	302·5	1·7	11
				1900·621	127·2	1·5	17
β Delphini β 151	...	20 33	+14 15	1892·758	330·4	0·4	3
				3·702	341·5	0·5	15
				6·857	355·3	0·7	7
				7·648	359·6	0·7	5
				8·711	2·4	0·8	20
				1900·655	8·0	0·7	23

Name.		R.A.	Dec.	Date.	Position Angle.	Distance.	Nights.
		h m	° ′		°	″	
λ Cygni OΣ 413	...	20 43	+36 8	1890·734	77·5	...	2
				2·706	73·4	...	2
				3·588	71·8	0·7	30
				5·714	73·8	0·6	3
				6·871	70·5	0·6	5
				7·564	69·1	0·6	5
				8·754	68·9	0·6	11
				1900·648	64·8	0·6	18
ε Equulei Σ 2737	...	20 54	+ 3 55	1896·842	284·6	0·7	3
				8·746	282·2	0·8	11
				1900·652	289·8	0·6	10
61 Cygni Σ 2758	...	21 2	+38 16	1895·597	124·0	20·3	1
				1900·857	124·9	22·0	7
δ Equulei OΣ 535	...	21 10	+ 9 37	1896·842	201·3?	...	3
				8·775	201·8	...	7
52 Pegasi OΣ 483	...	22 54	+11 12	1896·875	218·6	1·0	5
				7·663	219·2	1·0	3
				8·870	218·5	1·0	7
				1900·637	220·4	1·0	4
85 Pegasi β 85	...	23 57	+26 34	1896·875	208·0	0·8	5
				7·638	223·3	0·7	4
				8·816	234·4	0·7	8

Observations of Mars made at Mr. Edward Crossley's Observatory, Bermerside, Halifax, during the Opposition of 1900–1901. By Joseph Gledhill.

The following observations were made with the 9-inch photo-visual object-glass of the Cooke Equatorial. The powers used were 240 and 330. The observing conditions were almost invariably poor, and never really good.

1901 February 11, 9^h. The Kaiser Sea was about central, and formed a very striking feature; its extreme northern portion, where it is joined to the western end of Nasmyth Inlet, was not seen. Nasmyth Inlet and Lassell Sea were often but not steadily seen. The dark Knobel Sea lay near the eastern limb. The N. polar cap was of course a very prominent feature;

its surface and southern edge were carefully examined, but no markings or irregularities of outline were seen. The beautiful ruddy colour of Beer Continent was well seen, and it extended quite up to the eastern limb of the planet. On this and every other clear night the terminator was very frequently examined for protuberances or projections, but none were seen.

The details of the features about the S. pole were never well made out during this opposition.

No markings of any kind were ever seen in the central portions of Beer Continent or Secchi Continent.

February 13. Much motion. Saw all that was seen on the 11th and saw it much better. Delambre Sea lay close to the western limb. So also on February 14.

February 17. Clear night; much motion; definition as bad at midnight as at 9^h. The Kaiser Sea was about central at $11\frac{1}{2}^h$. The features seen were as above, with the exception of the beautiful warm colour of the Beer Continent, which was not seen. Main Sea was often looked for but never seen.

March 12. Much motion and flare; planet examined at short intervals for some six hours. Knobel Sea dark and very prominent. The curved band of seas to the N. of the S. pole was also an easy feature, but details could not be seen. The S. end of Knobel Sea extended as far S. as the centre of the disc. The curved broad band of seas was greenish.

March 16. Fair definition to-night. At 8^h several features were pretty well seen, and so remained for hours. The broad band round the S. pole was darkest at its eastern end, *i.e.* De la Rue Ocean; then, to the west, was the lighter Phillips Island. The region round the S. pole was nearly as bright as Beer Continent, which occupied the western half of the central part of the disc. Dawes Forked Bay and Burton Bay were dark as usual. The western limb was much brighter than the eastern; the darkest portion of the limb was where De la Rue Ocean touched it. Knobel Sea lay to the east of the central meridian, and extended from near the N. polar cap to about the equator of the disc; it has always, during this opposition, been one of the darkest features visible. To the west of this sea lay two streaks, slanting from N.W. to S.E., viz. a branch of Delambre Sea and Lassell Sea; these were faint markings, the latter being the darker of the two. There was a faint red glow over Beer Continent.

March 21, 8^h. The western edge or limb very bright; nearly as bright as the N. polar cap; this brightness extended inwards to a distance equal to about one-fifth of the radius of the planet. The eastern limb was not nearly so bright. The Kaiser Sea was a fine object, and lay just west of the central meridian. The N. edge of Herschel II. Strait was dark; the

region including Dawes Ocean was much brighter; still brighter was Lockyer Land round the S. pole. The fine line joining the Kaiser Sea (its N. end) to the extreme western end of Nasmyth Inlet was seen occasionally. Nasmyth Inlet and a narrow band parallel to it to the north (an arm of Delambre Sea) were also seen. Beer Continent was of a uniform delicate red colour. At 10^h the Kaiser Sea lay far to the west of the central meridian, the dark N. edge of Herschel II. Strait (with the projecting bays), Nasmyth Inlet, Lassell Sea, the western part of Knobel Sea, and the arm of Delambre Sea were all well seen. No markings were seen on Beer Continent.

March 25, 8^h to 12^h. The features seen were about as on the 21st.

March 26, 9^h to 12^h. No warm colour E. or W. of the Kaiser Sea. The difference in brightness between the *p* and *f* limbs not at all marked as on the 21st.

March 28, $9\frac{1}{2}^h$. The Kaiser Sea was between the central meridian and the *f* limb; a dusky form lay close to *p* limb (Oudemans Sea?), and on its eastern side there was a bright circular area (Fontana Land?); the arm of Delambre Sea lay near (to N.W.) the N. end of the Kaiser Sea. A warm tint was spread over Herschel I. Continent. The *p* limb was bright; the *f* limb less so.

March 31, $9\frac{1}{2}^h$. The *p* limb very bright; the *f* limb less so. The Kaiser Sea lay near the *f* limb. Fontana Land, Oudemans Sea, Delambre Sea, seen as on 28th. The surface near the S. pole (Lockyer Land?) was bright.

April 1, 8^h. The bright circular Fontana Land was near (a little to E.) the central meridian and the centre of the disc. Oudemans Sea was close to the west side of Fontana Land, and was a narrow marking. The *p* limb was very bright, and the brightness extended one-fifth of the radius inwards; the *f* limb was not bright. The curved band extending from limb to limb to the N. of the S. pole was dark; it was Maraldi Sea, &c.

April 10. Definition very bad; bright *p* limb as on the 1st. No warm colour on the disc.

April 11, 8^h. Bad definition; little clear sky. The *p* limb was very bright, and the brightness extended inwards as on the 1st. The darkest marking was at the N. edge of the broad curved band near S. pole, and close to the *p* limb. The only other markings seen were two faint streaks lying one near the centre of the disc and one between that and the N. pole. The curved broad band near the S. pole was faint.

April 13, 8^h. The small dark marking on the N. edge of the faint curved band of seas, &c., near the S. pole was on the inner edge of the very bright lune which lay along the *p* limb.

The two faint slanting markings, one passing through the centre of the disc (from N.W. to S.E.), and the other to the N. of it and parallel to it, were again seen as on the 11th. Secchi Continent probably occupied all the middle region of the disc; its eastern portion had less warm colour than the rest.

April 23, 9^h. Knobel Sea, dark, extended from the N. polar cap to the centre of the disc. Airy Sea lay to the east of it, and Lassell Sea to the west. The forked bays in Herschel II. Strait were also seen. No warm colour on the disc. The bright Rosse Land not seen. The bright yellow region near the S. pole was probably Jacob Land. The *p* limb was not very bright; it was very bright on the 20th and 21st. On the 24th the same features were seen as on the 23rd.

April 25, 8^h to 9^h. Knobel Sea was near the *f* limb, and the Kaiser Sea lay close to the *p* limb as a dark line. When the Kaiser Sea entered the very bright lune along the *p* limb it disappeared or became very faint indeed. There was a very slight warm (ruddy) colour over the central portion of the disc.

April 26, 8^h and 9^h. The Kaiser Sea lay near the *p* limb and along it; the darkest part of the sea could be seen when quite inside the bright lune, which lay along the *p* limb. Knobel Sea was near the *f* limb. The greenish band of seas and lands to the N. of the S. pole was the only other feature seen. Lockyer Land was seen as a bright yellow region surrounding the S. pole. Later, the forked bays seen, dark; Lassell Sea glimpsed now and then.

April 30, 8^h and 9^h. The Kaiser Sea near the central meridian; its faint and narrow northern portion was near the centre of the disc. This narrow portion was not seen to extend up to the western end of Nasmyth Inlet. Nasmyth Inlet and Lassell Sea not well seen. Delambre Sea and Lockyer Land seen. Flammarion Sea, dark, was seen quite up to the *p* limb. Dawes Ocean extended quite up to the *f* limb without any loss of distinctness or tone.

Lyrids, 1901 *April, observed at Cambridge.*
By J. C. W. Herschel.

1. I watched for the *Lyrid* meteors on April 12 and 17 to 22 to see whether I could trace any motion of the radiant, as suspected by Mr. Denning. I noted down 60 meteors, of which 40 came from the neighbourhood of *Lyra.* Of these I have rejected 6 as not well enough noted to use, and 2 as being too far from the radiant (see § 4). The remaining 32 distribute themselves among six centres, as tabulated below.

Mean Centre. α δ	Ap. 12.	Ap. 17.	Ap. 18.	Ap. 19.	Ap. 20.	Ap. 21.	Ap. 22.	
I. 267·9 + 28·1	...	...	...	...	1	2	...	= 3↓'s
II. 273·5 + 27·7	...	...	...	1	2	1	...	= 4
III. 274·5 + 33·6	...	...	...	1	1	1	3	= 6
IV. 278·0 + 37·3	2	1	1	1	4	2	...	= 11
V. 278·1 + 30·8	...	...	...	1	0	3	1	= 5
VI. 281·4 + 32·5	...	...	...	...	1	2	...	= 3

Unfortunately none of these centres furnished enough meteors day by day to give a satisfactory daily determination of the radiant point; the crossing point of two meteors is not enough to build evidence upon; if motion exists, I have not enough data to show it (but see § 8). But, on the other hand, as all the tracks pass within one degree of their assigned radiants—and none have been omitted because they would not fit in—I can fairly treat the radiants as stationary, and on this assumption I find (without weights) the mean centres for the whole period, as given in the first column. The effect of zenith attraction would be less than $\frac{3}{4}$°.

2. With many lines crossing each other at all angles over a small space there are sure to be several points of concentration or apparent radiant points, and it is by no means easy to distinguish the real from the fortuitous. These *Lyrids*, for instance, show more apparent radiant points than the six I finally chose; and it may be of interest if I describe in general terms my method of discrimination.

Perhaps one or two will be so strongly determined as to stand out obviously. Four meteors (or at the least three well noted ones) are necessary for this first step. Such are radiants III. and IV. Eliminating these by making a fresh tracing of the rest will probably eliminate also one or two fortuitous centres, and bring out more clearly weaker radiant points, indicated by short close meteors. Even two only may be enough as an *indication* for the second step. Radiant VI. was found in this way from the 7th and 8th meteors given in table, § 4. For the third step a single meteor is enough if it has been also observed elsewhere (radiant II.); and, finally, a radiant point given by a doubly observed meteor not seen at all by the observer can be taken as an indication (*e.g.* radiant I.). On going through this process for the first time it is very likely that, if any are left, they will seem to be stray single ones, and unassignable; but by repeating the process several times, and reassigning meteors which pass through more than one radiant, and may belong to either, an arrangement will most probably be found to suit them all, with a fair probability of its being the right arrangement.

3. Five of the meteors seen here were observed elsewhere. Professor Herschel has found their real paths and radiant points, and the following particulars of their courses, with notes on two of the paths which were derived from triple observations, are taken from a list of sixteen such real path determinations of meteors seen this year on April 13–21, which he kindly supplied me with.

Date. April.	Statn.	Hour. G.M.T.	Mag.	Dur.	From α	From δ	To α	To δ	Description.	Heights (miles) at Beginning.	End.	Length m.	Speed m/s.	Theor. Speed.	Radiant. α δ
19*	S.	12 45½	> 1	0·6	354°	+77°	30°	+73°	wh., no str.	77m over 6m	54m over				265° + 24°
	C.	12 46	1	1·0	212	+64	165	+64	orange, broad str. 1s.	N. of Ramsey, Hunts.	6m NNE. of Oundle, Notts.	32	32	32¼	± 1½° 19° S. of E.
	M.	12 45	2	v. quick	258	+11	250	− 3½							alt. 14½°
20†	Ba.	10 25	2	...	298	+42	317	+43	...	57m over North	52m over do.				220° − 21°
	C.	10 22	1	1·6	283½	+38½	296	+44	red or yellow	Sea, 2° 44′ E.	2° 20′ E.	32	20	24½	32° S. of E.
	M.	10 21	2	r. slow.	255	+ 7	261	+11½	...	53° 11′ N.	53° 33′ N.				alt. 14½°.
20	C.	11 36 (used for radiant II.)	♃	1·2	255	+47½	236	+57	wh., str. ½s dirn. well noted.	70m over 4m	49m over 2m				274° + 28°
	M.	11 35	1	r. quick	252	+ 1½	245	− 7½		N.W. of Halesworth, Suffolk.	S. of Mildenhall, Suffolk.	40	33	32	6° N. of E. alt. 32°.
21	C.	11 35	1	slow.	11	+57	24	+50	length & dirn. approx.	55m over 55m	37m over 48m				241° + 5°
	M.	11 34	2	quick.	300	+42	323	+45	...	E. of Saltburn, Yorks.	E. of Sunderland, Durham.	34	...	28	40 S. of E alt. 32½°.
21	C.	11 45½	> 1	1·5	210	+64	163	+61½	± broad red or yel. str. 1s.	69m over 2m.	56m over 3m.				272° + 23°
	M.	11 44	3	v. quick	245	+ 1	240	− 3½	...	N.W. of Ely, Camb.	S. of Holme, Hunts.	25	17	33½	2° S. of E. alt. 32°.

I also add, as found by Mr. Denning (used for radiant I.):

Date. April.	Statn.	Hour. G.M.T.	Mag.	Dur.	From α	From δ	To α	To δ	Description.	Heights (miles) at Beginning.	End.	Length m.	Speed m/s.	Theor. Speed.	Radiant. α δ
21	B.	10 9	= ♃	1·8	278½	+52	304	+70	slowish, str. 7s.	81m over 5m	51m over 3m				
	M.	10 7	> 1	quick.	200	+ 8	178	− 4	str. 3–4 sec.	S.W. of Stanford, Rutland.	E. of Droitwich, Worcestershire.	72	40	[30½]	268 + 30.

The observers and stations were :—

S. Professor Herschel, at Slough.
B. Mr. Denning, at Bristol.
M. Mr. Brook, at Meltham, near Huddersfield.
Ba. Mr. Holmes, at East Barnet.
C. Mr. Herschel, at Cambridge.

Notes.

* This meteor may have been a Lyrid from about $266° + 26°$, the middle point on the Cambridge backward path, between the tolerably broadside intersections with it, about $3\frac{1}{2}°$ apart, of the two backward Slough and Meltham paths, at $265° + 27°$ and $267° + 24°$. The latter two paths, directed in *Cepheus* and *Ophiuchus* almost oppositely away from Lyrid points on their path-lines at $266° + 30°$ and $271° + 30°$, diverged with small inclination to each other in their crossing, from a point of concurrence several degrees south of all those places, at $263° + 19°$, and in the narrow-based triangle with this acute-angled summit, a point as nearly as possible equidistant from its three sides was taken, at $265° + 24°$, as given in the list for the real path's mean radiant-point. Should the Cambridge path's direction, however, as seems more reasonably probable, have been exactly right, the mean radiant, found as above from the two other paths' very broadside intersections with it, would be at about $266° + 26°$, more nearly included in the Lyrid radiant area than the supposed point, as given in the table, at $265° + 24°$.

† Although the three times of appearance differ rather largely (which recurred, however, similarly in the same lists in other accordance cases), these three path-descriptions all certainly referred to the same meteor, which, appearing in an unusual quarter, E. and N.E., in the Meltham and East Barnet lists, agreed perfectly in those lists in base-line direction and amount of displacement from the Cambridge path. The two best situated paths, at Cambridge and Meltham, to fix the radiant-point gave a backward intersection at $231° - 12°$, near β *Libræ*, and of that point's exact correctness there could be no doubt had the East Barnet path conformed to it. Mr. Holmes' observations there were a first experience in meteor mapping, and the mapped track was so far astray in its direction as, when lengthened backwards, to cross the Cambridge path itself about one-third way from its commencement, and, carried further back, it was so nearly parallel to the mapped course at Meltham as not to intersect that track's back-prolongation at any point above the southern sensible horizon. As there is a marked region of active, though not yet well located radiant-points during the April meteor period on the south-western side of *Libra*, although the above intersection point at $231° - 12°$ is not far from the positions, $234\frac{1}{2}° - 13\frac{1}{2}°$ and $235° - 15°$, given in Mr. Denning's General Catalogue and in his list of co-Lyrid meteor-showers (in *Astr. Nachr.* No. 3513) of the notable April shower of η *Librids*, the rather dubiously small angle at which the chief pair of paths converge to it, and the third path's apparent alignment to some more southward radiant-focus, made the presumed radiant-point at $220° - 21°$ adopted in the list, $14°$ along the medial direction axis of the Cambridge and Meltham path-lines, backwards from their simple intersection, commend itself for trial and assumption, as several recorded meteor-paths in this and last year's Lyrid watches appeared to diverge very consistently and distinctly from a productive focal centre there, near ι *Libræ*. For a similar reason of a suspected meteor-shower near β *Libræ*, a real path of this meteor, differing but little from the present one, was extracted from its three recorded paths by Mr. Denning, with an adopted radiant-point at $227° - 16°$, on the same line of mean direction, but only $7°$ behind the place of intersection of the two chief backward path-lines noted at Cambridge and Meltham. Those two path-lines both pass backwards within one degree of that assumed position, and within two degrees of the radiant-point position near ι *Libræ* used in this real path's construction.

4. In *Monthly Notices*, 1899 March, vol. lix., p. 333, Mr. Denning says: "In endeavouring to find whether motion occurs in a radiant, only such meteors should be utilised as are well observed, and situated near their radiants. If observers set themselves to accumulate observations of this kind, we should in a few years have the means of disposing of some vexed questions in this branch of observational astronomy."

(I was glad to light upon this opinion, for nearly all my tracks *end* within 45° of *Vega*, this being as large a field as I have found that I can properly watch, and I had to let some half-dozen *Lyrids* go on this account, besides the two mentioned in § 1). Accordingly I give a list of my best observed meteors. I give the places accurately as plotted at the time, but the decimal is of course uncertain. The last column gives the perpendicular on the track from the assigned radiant point as a measure of the accuracy.

Date. April.	Hour. G.M.T.	Mag.	Dur. Sec..	From α δ	To α δ	Description.	Radl. Assigned. α δ	P, in arc.
1901	h m							′
12	*11 15	2	...	285·4 + 32·3	290·5 + 27·4	blue.	278·0 + 37·3	17
	*11 30	2	...	288·5 + 37·5	295·4 + 37·0	,,	,, ,,	24
17	12 48	> 1	·4	289·6 + 31·1	293·6 + 28·8	bright blue.	,, ,,	17
18	11 44	1	·2	281·1 + 33·7	282·3 + 31·7	,,	,, ,,	11
19	11 12	1·5	·9	305·2 + 33·7	312·6 + 31·7	red, on horiz.	,, ,,	31
	14 43	2	1·0 ±	255·6 + 35·4	239·8 + 35·7	wh., sl. str.	278·1 + 30·8	13
20	14 15	1	1·1	280·0 + 37·5	279·4 + 40·0	,, ,,	281·4 + 32·5	10
21	10 52	1	·7	270·7 + 36·1	265·4 + 37·0	white.	,, ,,	10
	12 49	1	·6	253·2 + 29·6	247·2 + 26·8	bright blue.	278·0 + 37·3	5

5. For a first determination of the radiant point without weights I have used a simplification of Schiaparelli's graphic method, for which I am indebted to Mr. H. C. Plummer. Schiaparelli drops perpendiculars on all the tracks from three corners of a square round the assumed radiant. Mr. Plummer uses two points on the axes (and the origin implicitly). Indeed, it is evident that two conditions ought to be enough to find the two coordinates required:

Let $x \cos \alpha + y \sin \alpha - p_0 = 0$ be the equation to a meteor; then

$$\left.\begin{aligned} x\Sigma \cos^2\alpha + y\Sigma \sin\alpha\cos\alpha - \Sigma p_0 \cos\alpha = 0 \\ x\Sigma \sin\alpha\cos\alpha + y\,\Sigma \sin^2\alpha - \Sigma p_0 \sin\alpha = 0 \end{aligned}\right\}$$

give the radiant. Let $(x,y)'$ and $(x,y)''$ be the coordinates of the feet of the perpendiculars on each track from $(0,\lambda)$ and $(\lambda,0)$, where λ is *any* convenient length, and putting

$$\sigma_1 = \Sigma x',\ \sigma_2 = \Sigma x'' \qquad \tau_1 = \Sigma y',\ \tau_2 = \Sigma y'' \qquad n = \text{no. of } \downarrow\text{'s}$$

* Observed at Littlemore, near Oxford, long. 1° 13′ W. lat. 51° 43′ N.

the equations are easily transformed into

$$x(\tau_1-\tau_2)+y(\sigma_2-\sigma_1) \qquad\qquad =\lambda(\sigma_2+\tau_1-n\lambda)$$
$$x(\sigma_1-\sigma_2+n\lambda)+y(\tau_1-\tau_2-n\lambda)=\lambda(\sigma_1-\tau_2)$$

It is often convenient to take one λ, or both, negative: this is equivalent to turning round the axes; it is less confusing to turn round the equations; the appropriate changes are readily found.

6. I have made use of Mr. Cookson's expression (as corrected by Mr. Plummer) (*Monthly Notices*, 1901 January and March), to find the weights. I have left over the probable errors until I have accumulated more observations. The term depending on p_r (the perpendicular from the graphically deduced radiant point, § 5) I have found to be *always* negligible, so that the expression for the weight, g, reduces to

$$g=\frac{D^2}{P}$$

simply,* with the curious result that the weight is independent of the accuracy as to direction—the only element used in the graphic method—and I should define the criterion of a meteor's right to be included in the determination of a radiant to be, "when the p term begins to be sensible the meteor's right begins to be doubtful." The weight, then, is a rough measure rather of the *usefulness* of including the meteor than of its *right*. Weighting the equations would alter my radiant points less than half a degree.

7. In a list which Mr. Denning has kindly sent me of Lyrids and others seen by him at Bristol between April 13–24 he has grouped together twenty meteors as Lyrids without assigning a definite radiant point. They form, in fact, just such a group as I start with, and discussing them in the same way as I have mine, I find that the group readily splits up into five radiant points, three of which confirm mine:—

Bristol.		Cambridge.	
α	δ	α	δ
267	+30	268	+28
268·5	+32·5		
270	+33		
274	+27	273·5	+28
273·5	+33·5	274·5	+33·5

* D is the length of the meteor-track

$$P=l^2(\lambda^2+l+D^2)+\overline{l+D}^2(\lambda^2+l^2)+p_r^2(l^2+\overline{l+D}^2)$$

in which λ, the radius of projection, or scale of the map, can be put = unity, and l is the distance of the beginning point of the meteor-track from the foot of the perpendicular p_r. This is a slight transformation of Mr. Cookson's formula, which I have found more easy to use in practice. P, as a whole, is identically the same, and $p_r^2(l^2+\overline{l+D}^2)$ is the negligible term.

The two distant meteors I have rejected, and one which I have assigned to Radiant III. may have come from 270+33. Mr. Denning's meteors were mostly on the 21st; there are not enough on other days to prove motion of the radiant.

8. Radiant IV. is probably quite a distinct stream from the true Lyrids (see Denning's Catalogue). Its characteristic bright blue meteors (§ 4) like Roman candles are in strong contrast to the red broad-streaked Lyrids. As to the others (though one must be cautious in drawing deductions from so few meteors), they show no tendency to sequence of appearance in time, *i.e.* to one radiant in motion, but rather contemporaneous activity; and, further, they occupy an area about 10° by 5°, whose length lies much in the same direction as the suspected motion. May not an area of such a shape give the impression of a radiant in motion, and yet really contain stationary radiant points with perhaps variable activity? The shape also suggests some spreading action *in process*, such as Professor Turner suggests as an explanation of stationary radiants; but if so, I do not see how it can be due to the Earth, as it is not parallel to the ecliptic, but to the Milky Way.

Corrections to reduce the Revised Madras Catalogue of Stars for 1835·0 *to the Fundamental Catalogue of Auwers* (*Pub. Ast. Gesell.* xiv. and xvii.). By A. M. W. Downing, M.A., D.Sc., F.R.S.

In the recently issued edition of Taylor's Madras Catalogue for 1835 the clock errors were determined from the right ascensions of standard stars in Auwers' Fundamental Catalogue (*Pub. Ast. Gesell.* Nos. xiv. and xvii.), whilst the index errors were determined from the declinations of the same catalogue corrected so as to represent Auwers' Mean System (*Ast. Nach.* No. 1536).

It may be of interest to give here the corrections applicable to the places of the Revised Madras Catalogue to reduce them to the system of Auwers given in *Pub. Ast. Gesell.* Nos. xiv. and xvii.

It should be noted that the mean $\Delta\alpha$ is $+^{s}\cdot015$ from 402 stars, and the mean $\Delta\delta$ is $-0''\cdot44$ from 297 stars.

The limits of declination for $\Delta\alpha$ and $\Delta\delta$ are determined by the limits adopted for the stars used for clock error and index error respectively.

TABLE I.

Corrections in order of Declination.

Limits of Dec.	Δα	Number of Stars.	Δδ	Number of Stars
° °	s		"	
+70 to +60	+·101	26		
60 „ 55	+·075	19		
55 „ 50	+·038	12	+0·37	14
50 „ 45	+·061	18	+0·47	18
45 „ 40	+·092	19	+0·14	21
40 „ 35	+·056	27	−0·20	28
35 „ 30	+·029	19	−0·13	21
30 „ 25	+·019	24	−0·08	26
25 „ 20	+·019	28	−0·77	24
20 „ 15	+·015	26	−0·65	26
15 „ 10	−·030	26	−1·08	26
10 „ 5	−·022	28	−0·64	29
+ 5 „ 0	·000	24	−0·96	23
0 „ − 5	−·017	18	−0·61	19
− 5 „ 10	−·019	18	−0·90	22
10 „ 15	−·028	21		
15 „ 20	−·032	20		
−20 „ −25	−·043	29		

TABLE II.

Corrections in order of Right Ascension.

Limits of R.A.	Δα	Number of Stars.	Δδ	Number of Stars.
h h	s		"	
0− 1	+·023	17	−0·49	11
1 − 2	+·009	21	−0·84	14
2− 3	+·037	18	−0·40	15
3− 4	+·007	22	−0 68	16
4− 5	−·017	18	−0·58	15
5− 6	+·019	27	−0·45	24
6 − 7	+·016	14	−0·70	8
7− 8	−·014	13	−0·20	11
8− 9	+·021	12	−0·24	8
9−10	−·011	14	−0·63	9
10−11	+·042	18	−0·25	7
11−12	−·006	18	−0·69	13
12−13	+·035	11	−0·42	5
13−14	+·022	11	−0·36	6

Limits of R.A.	Δα	Number of Stars.	Δδ	Number of Stars.
h h	s		"	
14–15	–·011	15	+0·51	14
15–16	+·007	16	–0·19	18
16–17	+·034	16	–0·40	12
17–18	–·028	13	–0·58	12
18–19	–·006	15	–0·37	11
19–20	+·051	17	–0·33	17
20–21	+·050	23	–0·73	15
21–22	+·034	18	–0·43	12
22–23	+·012	21	–0·60	13
23–24	+·026	14	–0·47	11

TABLE III.

Reduction Table.

Dec.	Δα	Δδ	R.A.	Δα	Δδ
°	s	"	h	s	"
+65	+·101		0	+·009	–·04
60	+·084		1	+·001	–·22
55	+·057		2	+·008	–·18
50	+·050	+·42	3	+·007	–·10
45	+·077	+·31	4	–·020	–·19
40	+·074	–·03	5	–·014	–·07
35	+·043	–·17	6	+·002	–·14
30	+·024	–·11	7	–·014	–·01
25	+·019	–·43	8	–·012	+·22
20	+·017	–·71	9	–·010	·00
15	–·008	–·87	10	·000	·00
10	–·026	–·86	11	+·003	–·03
+ 5	–·011	–·80	12	·000	–·12
0	–·009	–·79	13	+·014	+·05
– 5	–·018	–·76	14	–·010	+·52
10	–·024		15	–·017	+·60
15	–·030		16	+·006	+·14
20	–·036		17	–·012	–·05
–25	–·043		18	–·032	–·03
			19	+·008	+·09
			20	+·035	–·08
			21	+·027	–·14
			22	+·008	–·08
			23	+·004	–·09
			24	+·009	–·04

The limits of declination for Δα and Δδ are determined by the limits adopted for the stars used for clock error and index error respectively.

Errata in the Revised Madras Catalogue of Stars for 1835·0.

By A. M. W. Downing, M.A., D.Sc., F.R.S.

Herr Ristenpart has had the kindness to send me a list of discrepancies between the recorded places of stars in the Revised Madras Catalogue compared with other authorities. An examination of these has enabled me to draw up the following list of errata. I feel greatly indebted to Herr Ristenpart for the trouble he has taken in the matter.

No. 7. Mean Dec. 1835·0, *for* $-3^\circ\ 28'\ 38''\cdot67$ *read* $-3^\circ\ 28'\ 44''\cdot67$

No. 48. Mean Dec. 1835·0, *for* $+0^\circ\ 46'\ 22''\cdot71$ *read* $+0^\circ\ 46'\ 15''\cdot99$.

No. 320. Mean R.A. 1835·0, *for* $0^h\ 55^m\ 15^s\cdot32$ *read* $0^h\ 56^m\ 15^s\cdot32$. Precession in R.A., *for* $+3^s\cdot106$ *read* $+3^s\cdot107$. Mean Dec. 1835·0, *for* $+6^\circ\ 9'\ 48''\cdot60$ *read* $+6^\circ\ 9'\ 48''\cdot64$. Precession in Dec., *for* $+19''\cdot478$ *read* $+19''\cdot457$.

No. 701. Star's name, *for* 16 Arietis *read* Taylor 705. Delete the references to Bradley and Piazzi.

No. 2928. Mean R.A., 1835·0, *for* $7^h\ 8^m\ 57^s\cdot85$ *read* $7^h\ 7^m\ 57^s\cdot85$. Mean Dec. 1835·0, *for* $+9^\circ\ 44'\ 59''\cdot85$ *read* $+9^\circ\ 44'\ 59''\cdot74$. Precession in Dec., *for* $-5''\cdot945$ *read* $-5''\cdot862$.

No. 3609. Taylor's No., *for* 3626 *read* $\left\{\begin{matrix}3625\\3626\end{matrix}\right\}$.

No. 3965. Mean R.A. 1835·0, *for* $8^h\ 59^m\ 51^s\cdot66$ *read* $8^h\ 59^m\ 51^s\cdot69$. Mean Date in R.A., *for* 31·98 *read* 32·11. No. of Obs. in R.A., *for* 7 *read* 12.

No. 3966. Mean R.A. 1835·0, *for* $8^h\ 59^m\ 51^s\cdot74$ *read* $9^h\ 0^m$ ... Mean Date in R.A., *for* 32·29 *read* ... No. of Obs. in R.A., *for* 5 *read* .... Precession in R.A., *for* $+3^s\cdot467$ *read* $+3^s\cdot465$. Mean Dec. 1835·0, *for* $+22^\circ\ 39'\ 42''\cdot29$ *read* $+22^\circ\ 39'\ 42''\cdot12$. Precession in Dec., *for* $-14''\cdot173$ *read* $-14''\cdot236$.

No. 5965. Mean Dec. 1835·0, *for* $-2^\circ\ 29'\ 47''\cdot17$ *read* $-2^\circ\ 28'\ 47''\cdot17$.

No. 5966. Mean Dec. 1835·0, *for* $+31^\circ\ 39'\ 37''\cdot45$ *read* $+31^\circ\ 40'\ 37''\cdot45$.

No. 6040. Star's name, *for* Brisbane 4355 *read* Brisbane 4344. Mean R.A. 1835·0, *for* $13^h\ 2^m\ 9^s\cdot11$ *read* $13^h\ 1^m\ 9^s\cdot15$. Precession in R.A., *for* $+3^s\cdot661$ *read* $+3^s\cdot651$. Mean Dec. 1835·0, *for* $-58^\circ\ 41'\ 47''\cdot99$ *read* $-58^\circ\ 41'\ 47''\cdot91$. Precession in Dec., *for* $-19''\cdot326$ *read* $-19''\cdot348$.

No. 6413. Mean Dec. 1835·0, *for* $+22^\circ\ 5'\ 16''\cdot61$ *read* $+22^\circ\ 5'\ 10''\cdot45$.

No. 6718. Mean R.A. 1835·0, *for* $14^h\ 17^m\ 9^s\cdot62$ *read* $14^h\ 18^m\ 9^s\cdot62$. Mean Dec 1835·0, *for* $-0^\circ\ 20'\ 15''\cdot12$ *read* $-0^\circ\ 20'\ 15''\cdot20$. Precession in Dec., *for* $-16''\cdot572$ *read* $-16''\cdot522$.

No. 7233. Mean R.A. 1835·0, *for* $15^h\ 24^m\ 42^s\cdot92$ *read* $15^h\ 24^m\ 45^s\cdot37$. Precession in Dec., *for* $-12''\cdot574$ *read* $-12''\cdot572$.

No. 10179. Magnitude, *for* 9 *read* 6.

Nautical Almanac Office:
1901 *June* 22.

Errata in Monthly Notices, vol. lxi. p. 128.

Line 12, equation (15) should read *as follows*:

$$p=(2-e^2\pm 2\sqrt{1-e^2})/e^2=(1\pm\sqrt{1-e^2})^2/e^2$$

and equation (16) should read *as follows*:

$$OS=e(1+p)=2\sqrt{p}=(2\pm 2\sqrt{1-e^2})/e.$$

Add also these words:

"The lower sign is to be taken when $AB<OA$, as in figs. 4 and 6; and the upper sign when $AB>OA$, in which case the lower half of the ellipse is described first."

Same page, lines 22 and 23:

For the ellipse thus becomes a parabola, and S is at an infinite distance,

Read the ellipse thus becomes a straight line, and S is at one extremity.

[I am indebted to Dr. Otto Knopf for these corrections.—H. H. T.]

MONTHLY NOTICES

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Cape Double Star Results, 1900.*

(*Communicated by Sir David Gill, K.C.B., F.R.S., &c., His Majesty's Astronomer at the Cape of Good Hope.*)

The following measures of double stars, of which the great majority are due to Mr. Innes, were made with the 18-inch McClean telescope and the Repsold micrometer with bright wires. Red illumination was introduced on 1900 August 30. A few observations made in 1899 November and December are also included. New pairs found by Mr. Innes since the publication of his *Reference Catalogue of Southern Double Stars* are included. Estimates of these have been made by him at the 7-inch equatorial, and are quoted when the pair has not yet been measured with the McClean Telescope. Professor E. C. Pickering kindly communicated a list of pairs found at Arequipa, and measures of some of these have been made.

The programme undertaken is:

(*a*) The measurement of all southern pairs not yet measured. This includes the great part of those found here or found at Cordoba or Arequipa.

(*b*) The remeasurement of such of Sir John Herschel's pairs as have not been measured in the last forty years.

(*c*) The regular measurement of all southern rapid binary pairs.

(*d*) The remeasurement of pairs recently discovered but already measured elsewhere at one epoch only.

* Received 1901 February 11. Publication delayed owing to an oversight of the Senior Secretary.

Each pair will as far as possible be measured at least four times, in two groups of two nights each, separated by about one year. On the completion of this programme the individual observations will be published *in extenso* in the *Cape Annals*.

The observers in 1899–1900 were :—

L. ... Mr. J. Lunt. I. ... Mr. R. T. A. Innes.

A few check observations were made by—

G. ... Sir David Gill. G. J. ... Mr. G. F. Johns.

Generally each night's observation consists of four or five pointings for angle with measures of two double distances. When the observations are reduced and it is found that the two nights' results are not in fair agreement, the star has, when possible, been remeasured on a third or even fourth night. All stars were observed close to the meridian, and an endeavour was made to make observations on different sides of the meridian.

Every measure made is used, and where the results for different nights are weighted—which has only occurred on a few occasions—attention is directed thereto. The zero of the position angle was determined on nearly every night of observation. The results for α *Centauri* are given separately.

No search for new pairs was undertaken, but a few were found at different times, viz.—

31 pairs with the 18 inch McClean telescope by Mr. Innes.
13 „ „ „ 7·inch Merz equatorial by Mr. Innes.
6 „ „ „ transit circle by Messrs. Cox & Pead.
2 „ were taken from photographic plates, one by Mr. Johns and one by Mr. Innes.

Several distant stars have also been added to known double stars. A considerable number of proper motions have been specially determined and will be found in the last column.

[In the first column the No. only of the Ref. Cat. is given; the hour is to be inferred from the Right Ascension.]

Ref. Cat.	Star.		Mag.	1900. R.A. h m	1900. S.D. ° ′	Epoch.	Angle. °	Dist. ″	Diff. of Mags.	No. of Nights.	Obs.	Remarks.
1	λ 1 ...	...	8·8	0 1·0	30 53	1900·84	323·5	4·60	...	1	L.	
2	Harvard (Lac. 9721)	...	5·6	1·2	49 38	·01	177·1	5·20	4·9	2–1	I.	Many faint stars in field.
			"	"	"	·86	175·9	5·46	5·9	2	L.	
New	Harvard (Lac. 9740)	...	6·4	4·0	54 34	·86	291·0	0·81	3·2	2	I.	Discovery communicated by Professor E. C. Pickering. Fine pair. p.m. insensible.
5	κ_1 Sculptoris	...	6·0	4·3	28 33	·84	274·6	1·36	...	1	L.	
7	Innes 43 ...	...	6·9	5·7	73 47	·02	329·8	1·18	...	2–1	I.	
22	Innes 44 ...	...	8·2	23·5	55 11	·85	245·1	0·74	0·5	2	I.	
23	*h* 3370 ...	...	8·0	23·7	66 28	·86	63·7	40·0	...	2	L.	
24	Innes 177 (Lac. 113)	...	8·1	23·8	83 42	·85	17·2	1·05	0·9	2	I.	
27	β_2 Toucani	...	4·3	27·0	63 31	·36	297·9	0·76	0·2	2–1	I.	
			"	"	"	·71	302·9	0·81	...	1	L.	Most difficult.
28	Lac. 130 ...	AB	7·0	28·8	55 53	·85	274·0	0·51	0·3	3	I.	Innes 45.
		AB, C	"	"	"	·85	248·6	6·83	...	2	I.	*h* 3376.
34	Innes 46 ...	...	8·1	35·2	39 30	·61	331·4	1·95	2·3	1	I.	
			"	"	"	·70	327·9	...	...	1	L.	
36	*h* 3385 ...	...	8·7	36·0	41 45	·64	250·4	4·32	0·2	2	I.	Colours slightly contrasted.
	h 3390 (Lac. 187)		7·0	38·6	45 44	·85	312·3	14·1	2·5	1	I.	A yellow 4, B blue. No change since 1834·7. No material for p.m.
39	η Phenicis	...	4·5	38·9	58 1	·42	217·7	19·7	7·0	2	I.	

T T 2

Ref. Cat.	Star.	Mag.	R.A. 1900. h m	S.D. 1900. ° ′	Epoch.	Angle. °	Dist. ″	Diff. of Magr.	No. of Nights.	Obs.	Remarks.
40	UA 64 Toucani ...	6·4	0 40·2	63 3	1900·03	69·0	2·75	...	1	G.	
		,,	,,	,,	·03	68·1	2·51	...	1	I.	
		,,	,,	,,	·36	69·6	2·45	...	2	L.	
42	Harvard (Lac. 207)	5·7	41·1	48 6	·86	308·3	14·3	7·3	1	I.	A yellow 3.
45	Innes 261 ...	7·2	43·1	29 53	·84	49·7	<0·25	...	1	I.	Very doubtful if elongated. Angle always unknown to observer. Estimated angle in 1897 = 60° ±.
		,,	,,	,,	·86	53·2	...	...	1	I.	
48	Innes 47	6·6	47·2	44 15	·74	1·0	1·10	0·5	2	I.	Both white. The p.m. is very small.
58	Innes 48	7·2	54·0	67 6	·48	332·9	0·63	0·7	2–1	I.	Both yellow.
60	Innes 49	7·0	56·3	53 7	·84	42·8	0·75	0·3	2	I.	
64	*h* 3415	7·0	59·3	41 11	·87	151·0	0·95	1·0	1	I.	
New	Harvard (Cape 1880, 416)	7·3	59·4	41 4	·86	259·6	3·65	3·0	2	I.	A yellow 3. New pair communicated by Professor E. C. Pickering.
1	β Phenicis ...	3·4	1 1·6	47 15	1899·91	18·0	1·27	...	1	G.	
	,, ...	,,	,,	,,	1900·78	18·1	1·55	...	2	L.	
6	Innes 262 ...	·7	4·1	30 9	·84	168·9	0·76	0·8	2	I.	
9	Cape 1	8·3	5·0	40 40	·67	70·9	2·12	0·8	1	I.	
	,, ...	,,	,,	,,	·78	71·9	2·30	...	2	L.	
11	CZ. 1ʰ 152 ...	8·3	7·2	45 59	·67	70·5	2·86	0·2	1	I.	
	,, ...	,,	,,	,,	·86	68·3	3·17	...	2	L.	
New	Cape 26 ... ... (C.Z. 1ʰ 176)	8·7	8·0	49 48	1899·8	50 ±	1 ±	0·3	1	I.	Discovered at the transit circle by Mr. W. H. Cox.

Ref. Cat.	Star.	Mag.	1900. R.A. h m	1900. S.D. ° ′	Epoch.	Angle. °	Dist. ″	Diff. of Mags.	No. of Nights.	Obs.	Remarks.
13	Innes 27	7·3	1 11·6	69 21	1900·51	197·2	1·03	0·5	3	I.	Slight evidence of direct motion, but in κ Toucani, which is connected with this system, the motion is retrograde.
	„	„	„	„	·70	201·5	0·94	...	1	L.	
14	κ Toucani ...	4·9	12·4	69 24	·51	351·8	5·31	...	3	I.	
	„ ...	„	„	„	·70	353·3	5·18	...	2	L.	
15	Innes 50	9·0	12·7	37 48	·85	144·3	0·85	1·0	2	I.	
22	*h* 3430	6·8	16·5	57 52	1899·95	237·0	2·85	...	2	I.	Companion deep yellow. Angle decreasing slowly.
26	Innes 263 ...	7·2	19·0	70 14	1900·37	60·5	0·74	0·2	2	I.	
	„ ...	„	„	„	·72	63·0	0·84	...	1	L.	
New	Harvard (Lac. 388)	7·0	19·2	41 28	·86	240·5	4·47	4·3	2–1	I.	A yellow 4, B bluish. p.m. of A is α = [−0s·01]. δ = −0″·08.
31	Innes 264 AB	8·0	27·6	53 53	·43	121·2	0·51	0·2	2–1	I.	
	„ AB, C	„	„	„	·44	6·6	39·3	3·5	2	I.	
33	Innes 51	7·0	30·1	46 12	·85	13·0	1·77	2·9	2	I.	A yellowish 3, B bluish. p.m. of A = 0″·118 towards 31°·9.
35	τ Sculptoris ...	5·7	31·5	30 25	·89	94·2	1·96	...	2	L.	
37	*p* Eridani ...	5·3	36·0	56 42	·38	223·5	7·73	...	2	L.	
38	λ 15	7·8	36·4	22 13	·86	313·2	2·85	...	1	L.	
48	Innes 52	8·5	43·5	44 28	·86	181·2	0·65	0·4	1	I.	
55	χ Eridani ...	3·6	52·1	52 6	1899·96	197·6	6·24	...	2–1	I.	Common p.m.
56	*h* 3475	6·4	52·1	60 48	1900·11	49·6	2·61	...	1	I.	Slow increase in angle.
	„	„	„	„	·71	52·3	2·49	...	2	L.	
57	Cape 2	9·0	52·5	42 51	·68	94·8	3·28	0·5	2	I.	

Ref. Cat.	Star.		Mag.	1900. R.A.	1900. S.D.	Epoch.	Angle.	Dist.	Diff. of Mags.	No. of Nights.	Obs.	Remarks.
				h m	° ′		°	″				
61	Innes 265 ...		8·0	1 56·8	44 19	1900·86	25·4	0·79	0·7	1	I.	
5	*h* 3485		8·1	2 7·8	49 48	·76	140·5	4·13	...	2	L.	Fixed.
7	Innes 266 ...		7 6	10·4	66 37	·41	162·0	3·20	...	2	I.	A yellow, B blue.
12	*h* 3497 ...	AB	5·4	16 7	56 24	1899·96	81·5	33·3	5·1	1	L.	In *Ref. Cat.* delete "Harvard." No change since *h*.
	,,	AC	,,	,,	,,	·96	318·8	69·5	7·6	1	I.	New.
13	Innes 147 ...		7 7	17 9	48 46	1900·41	339·8	1·62	...	2–1	I.	
	,,		,,	,,	,,	·70	Not seen double			1	L.	
24	Innes 53		9·6	35·6	40 24	·10	331·0	4·09	...	1	I.	
	,,		,,	,,	,,	·86	330·4	3·54	...	1	L.	
New	Cape 27 (Lac. 1884)		7·9	39·1	88 50	·99	204·3	7·46	2·0	1–2	I.	Found by Mr. G. F. Johns on photo plates. It is somewhat surprising that such an easy pair should so long have escaped notice.
31	Innes 267 ...		8·0	41 8	41 39	·40	24·7	2·04	...	2	I.	
32	Innes 28		8·5	42·1	67 42	1899·96	Single	...	...	1	I.	The only pair near here is C.G.A. 2996+7 ($2^h\ 43^m{\cdot}6 - 67°\ 25'$).
35	C.Z. 2^h 1201	AB	9·0	44·3	60 34	1900·01	251·3	0·99	...	1	I.	Innes 268.
	,,	AB, C	,,	,,	,,	·01	215·4	21·1	...	1	I.	*h* 3534.
40	γ_2 Fornacis ...		5·6	45·6	28 21	·72	Single	...	...	1	L.	
43	Cordoba (6) ...		8·5	47·3	45 39	·40	181·2	3·67	0·2	2	I.	
46	Innes 148		7 6	52·3	63 25	·43	7 9	5·04	...	2	I.	
47	Cordoba (7) ...		8·0	52·7	39 51	·40	183·5	3·40	0·3	2	I.	
48	Innes 149 ...		9·4	52·8	23 47	·10	260·2	7·28	1·6	1	I.	

Ref. Cat.	Star.		Mag.	1900. R.A. h m	1900. S.D. ° ′	Epoch.	Angle. °	Dist. ″	Diff. of Mags.	No. of Nights.	Obs.	Remarks.
50	θ Eridani	...	3·1	2 54·5	40 42	1900·79	84·9	8·21	...	2	L.	
53	*h* 3549 ...	...	9·4	59·2	38 27	·10	277·2	5·96	...	1	I.	
4	Cape 3 ...	...	9·2	3 4·5	42 54	·06	249·8	2·61	...	1	I.	
5	Innes 54 ...	...	8 7	5·0	41 45	·c6	132·6	1·23	0·5	1	I.	
10	P. III. 19	AB	5·9	8·9	44 48	·01	182·6	0·97	0·7	1	I.	AB yellowish.
	,,	AC	,,	,,	,,	·01	210·7	3·47	...	1	I.	C bluish.
	,,	BC	,,	,,	,,	·01	220·4	2·65	...	1	I.	
New	Innes 341 (O.A. 2179)		8·5	13·6	19 26	·8	10 ±	1·3 ±	1·2	1	I.	Found with the 7-in. refractor.
20	Innes 56 ...	...	8·5	15·1	43 0	·50	256·4	3·36	2·7	2	I.	
21	Innes 150	...	8·2	15·9	63 26	1899·96	357·7	4·08	2·0	2	I.	
23	Innes 151	...	8·2	18·7	41 41	1900·95	160·4	1·23	0·3	2	I.	Both white.
27	Innes 57 ...	...	9·0	24·0	59 38	·48	210·8	2·38	1·0	2	I.	
28	Cordoba (χ_3 Fornacis)		6·6	24·3	36 12	·95	249·1	6·30	4·1	2	I.	Small star reddish. In *Ref. Cat.* delete Innes 58. Noted dpl. 6½, 10 in Uranometria Argentina.
61	Innes 269	AB	7·3	58·7	54 41	·02	80·0	3·55	...	2–1	I.	
	,,	,,	,,	,,	,,	·03	78·5	3·99	...	1	G.	
	,,	,,	,,	,,	,,	·03	75·4	...	...	1	L.	
	,,	AC	,,	,,	,,	·03	196·0	27·8	4·7	1	I.	New.
	,,	,,	,,	,,	,,	·03	195·4	27·8	...	1	L.	
[illegible]	Russell 38	...	6·4	4 0·9	85 34	·08	245·0	2·31	...	1	L.	

Ref. Cat.	Star.		Mag.	R.A. 1900. h m	S.D. 1900. ° ′	Epoch.	Angle. °	Dist. ″	Diff. of Mags.	No. of Nights.	Obs.	Remarks.
4	Innes 152 ...		7·6	4 1·2	35 43	1900·10	68·0	0·92	0·0	2–1	I.	
6	Innes 153 ...		7·1	4·4	33 7	·55	339·5	0·83	0·0	2	I.	Both white.
12	ν_4 Eridani ...		3·8	14·1	34 2	·06	Single	...	...	2	I.	Considered double with the 7-in. (Innes 270).
21	Innes 271 ...		7·5	18·5	43 1	·09	148·1	2·45	...	2	I.	} h 3646.
22	Lac. 1435	A, BC	7·2	18·6	41 27	·03	137·2	38·3	...	1	I.	}
	„	„	„	„	„	·03	137·0	37·6	...	1	L.	
	„	BC	„	„	„	·51	191·3	1·24	1·0	2–1	I.	Innes 272.
New	Innes 384 (P. IV. 81)		6·7	19·5	35 47	·55	187·0	18·8	7·1	2	I.	Found with the 18-in McClean refractor.
23	Σ 544		8·2	19·9	8 59	...	...	...	...	...	I.	In note in *Ref. Cat.* for "pr." read "f." (R.A. 4h 19m 54s).
26	Innes 59	AB	6·6	21·2	34 59	·09	198·0	42·4	3·4	1	I.	
	„	BC	„	„	„	·54	281·3	4·04	1·5	2	I.	
32	Innes 154 ...		7·5	27·6	35 59	·55	318·5	0·61	0·1	2–1	I.	
New	Cape 28		9·1	34·1	50 21	1899·9	300 ±	3 ±	0·7	1	I.	Discovered with transit circle by Mr. J. A. J. Pead.
39	h 3672		8·3	35·0	35 30	1900·54	300·2	4·48	0·7	2	I.	
43	Innes 60		9·0	38·1	45 54	·54	96·0	2·72	0·2	2	I.	
52	Cordoba (11) ...		8·0	46·7	39 21	·58	51·8	3·91	...	2	I.	Also seen at Madras in 1865.
New	Innes 342 (Lac. 1637) ...		7·5	47·4	54 4	·22	176·5	1·11	0·6	1	I.	} Found with the 18-in. McClean telescope.
„	Innes 343 (Lac. 1641) ...		7·8	47·7	54 37	·22	45·3	2·59	3·7	1	I.	}

Ref. Cat.	Star.	Mag.	1900 R.A. h m	1900 S.D. ° ′	Epoch.	Angle. °	Dist. ″	Diff. of Mags.	No. of Nights.	Obs.	Remarks.
54	*h* 3699 … …	7·7	4 47·7	45 50	1900·13	142·6	18·1	4·5	2	I.	No change in angle; *h* has 5″ ±.
56	Innes 273 …	9·0	48·1	45 6	·54	350·6	1·27	0·1	2	I.	
61	*h* 3707 … …	9·2	51·5	59 55	·17	269·0	8·79	3·5	1	I.	No nebula seen.
New	Innes 344 … (C.Z. 4^h 1849)	8·5	54·2	51 36	·60	21·5	1·80	2·3	2	I.	Found with the 18-in. McClean telescope.
1	Innes 274 …	8·0	5 0·3	50 56	·03	257·0	3·27	…	1	G.	
	" …	"	"	"	·03	257·9	3·20	…	1	I.	
	" …	"	"	"	·05	257·7	3·18	…	2	L.	
12	κ Leporis …	4·4	8·6	13 4	·12	359·9	2·54	…	1	L.	
14	Rigel A, BC	0·3	9·7	8 19	·18	202·9	9·36	…	1	L.	
19	Howe (C.Z. 5^h 381)	8·3	11·6	29 37	·07	237·2	2·46	…	1	L.	
22	Cordoba (13) …	8·8	14·0	27 36	·21	93·8	3·34	0·2	1	I.	
30	Peters … (Bradley 757)	7·2	18·8	0 58	·10	167·1	2·16	…	1	L.	
34	Innes 275 …	8·2	19·9	36 46	·15	1·7	1·62	0·5	2	I.	
New	Innes 345 … (θ Pictoris)	6·3	22·5	52 24	·60	199·2	0·43	0·6	2	I.	Found with the 18-in. McClean telescope. As a wide pair this is Dunlop 20. p.m. in α uncertain, in δ = −0″·12.
New	Innes 346 … (P.V. 122)	5·9	23·9	41 2	1899·9	180 ±	20 ±	6·1	1	I.	Found with the 18-in. McClean telescope.
40	*h* 3768 … …	9·0	26·1	66 41	1900·21	…	…	…	1	I.	Nebula with star N.f. Nebula too diffused to be worth measuring as a double star.
1	Innes 276 …	6·4	27·5	68 42	·59	212·9	0·56	0·3	2–1	I.	

Ref. Cat.	Star.		Mag.	1900. R.A.	1900. S.D.	Epoch.	Angle.	Dist.	Diff. of Mags.	No. of Nights.	Obs.	Remarks.
				h m	° ′		°	″				
43	Innes 62 ...	...	8·0	5 27·8	47 16	1900·59	176·9	0·81	0·4	2	I.	
52	Harvard (Lac. 1922)	...	6·6	29·6	64 0	·48	68·4	8·65	4·4	2	I.	
67	*h* 3784 ...	...	8·2	35·4	46 9	·14	60·7	5·71	...	1	L.	Common p.m. of 0″·48 towards 199°·5.
70	α Columbæ	...	2·7	36·0	34 8	·06	358·0	11·6	9·3	1	I.	The measure differs considerably from Prof. See's;
	,,	...	,,	,,	,,	·32	Not seen		...	1	I.	on other occasions the companion was invisible.
New	Innes 347 (Lac. 2022)	...	8·0	36·3	75 18	·11	127·2	8·99	3·0	1	I.	Found with the 18-in. McClean refractor.
72	Innes 277	...	8·0	36·6	71 12	·04	189·9	3·94	...	2	I.	A yellowish, B bluish.
77	Innes 278	...	8·5	42·6	68 45	·11	170·0	1·06	...	1	I.	
81	*h* 3802 ...	...	8·1	43·4	55 46	·05	307·8	8·05	...	1	L.	
84	Jacob (3)...	...	5·8	45·0	14 31	·12	179·6	2·57	...	1	L.	
86	Innes 63	AB	7·1	45·7	48 57	·08	11·5	1·45	...	2	I.	
	,,	AC	,,	,,	,,	·08	211·4	31·8	5·0	2	I.	A 10m star S.f.
New	Innes 348 (O.A. 4412)		9·0	49·0	29 3	·3	80 ±	2·5 ±	1·5	1	I.	Found with the 7-in. refractor.
89	Innes 64	AB	5·6	49·1	37 39	·05	233·0	18·8	5·4	2	I.	
	,,	AC	,,	,,	,,	1899·98	16·1	44·9	5·9	1	I.	
95	Innes 155	AB	8·0	55·6	33 50	1900·25	18·4	1·70	...	2	I.	
	,,	AC	,,	,,	,,	·21	97·2	18·1	3·3	1	I.	New.
3	*h* 3834 ...	...	5·8	6 1·8	45 5	·14	225·8	4·06	...	1	L.	

Ref. Cat.	Star.		Mag.	1900. R.A. h m	1900. S.D. ° ′	Epoch.	Angle.	Dist.	Diff. of Magr.	No. of Nights.	Obs.	Remarks.
9	Innes 280 (C.Z. vi. 263)		9·0	6 6·7	46 20	1900·08	278°·0	8″·70	2·5	2	I.	There is a very faint pair about 50″ N.f. Identification and note in Ref. Cat. erroneous.
	„	...	„	„	„	·10	276·5	·11	4·5	1	L.	
New	Innes 349 (Lac. 2198)	...	7·0	10·7	29·34	·32	41·4	5·82	4·0	1	I.	Found with the 7-in. refractor.
4a	Cape 23 ...	...	8·5	11·8	49·5	·28	62·7	...	...	1	I.	
23	Innes 281	...	8·7	17·8	44 45	·09	6·6	6·37	...	2	I.	A yellow. The p.m. of the chief star is 0″·23 towards 90°·0.
28	Innes 282	...	7·7	21·7	50 29	·06	312·5	1·85	...	1	I.	
31	G Puppis ..	...	6·0	23·1	48 7	·08	132·6	1·42	...	3	I.	B is yellowish.
	„ ...	...	„	„	„	·12	136·2	...	...	1	L.	
New	Innes 350 (Lac. 2315)		7·5	26·0	45 43	·98	10·4	16·1	5·5	1	I.	Found on triple chart plate No. 5711.
40	β 754 ...	...	7·0	31·1	33 56	...	...	...	...	...	...	This pair has a common p.m. of 0″·118 towards 312°·6.
47	Innes 5 ...	...	6·6	36·9	61 27	·23	274·3	2·85	2·5	2	I.	
51	Cordoba (15)	AB	8·7	38·7	37 54	·22	277·8	4·13	1·3	2	I.	
	„	AC	„	„	„	·22	149·3	19·4	3·3	2	I.	New.
53	Innes 283	...	8·0	39·4	42 28	·18	181·4	2·62	...	2	I.	
55	Innes 179	...	6·9	41·2	30 29	·18	225·2	4·45	...	2	I.	Prof. See's angle requires + 20°.
57	Innes 284	...	8·5	41·6	64 25	·10	233·6	5·84	...	2	I.	
58	*h* 3891 ...	...	6·0	41·7	30 51	·17	225·0	5·06	...	1	L.	Prof. See's angle requires + 20°.
	„	...	„	„	„	·18	223·0	5·06	...	2–1	I.	

Ref. Cat.	Star.	Mag.	1900. R.A. h m	1900. S.D. ° ′	Epoch.	Angle. °	Dist. ″	Diff. of Mags.	No. of Nights.	Obs.	Remarks.
40	UA 64 Toucani ...	6·4	0 40·2	63 3	1900·03	69·0	2·75	...	1	G.	
		"	"	"	·03	68·1	2·51	...	1	I.	
		"	"	"	·36	69 6	2·45	...	2	L.	
42	Harvard (Lac. 207)	5·7	41·1	48 6	·86	308·3	14·3	7·3	1	I.	A yellow 3.
45	Innes 261 ...	7·2	43·1	29 53	·84	49·7	<0·25	...	1	I.	Very doubtful if elongated. Angle always unknown to observer. Estimated angle in 1897 = 60° ±.
		"	"	"	·86	53·2	...	...	1	I.	
48	Innes 47	6·6	47·2	44 15	·74	1·0	1·10	0·5	2	I.	Both white. The p.m. is very small.
58	Innes 48	7·2	54·0	67 6	·48	332·9	0·63	0·7	2–1	I.	Both yellow.
60	Innes 49	7·0	56·3	53 7	·84	42·8	0·75	0·3	2	I.	
64	*h* 3415	7·0	59·3	41 11	·87	151·0	0·95	1·0	1	I.	
New	Harvard (Cape 1880, 416)	7·3	59·4	41 4	·86	259·6	3·65	3·0	2	I.	A yellow 3. New pair communicated by Professor E. C. Pickering.
1	*β* Phenicis ...	3·4	1 1·6	47 15	1899·91	18·0	1·27	...	1	G.	
	" ...	"	"	"	1900·78	18·1	1·55	...	2	L.	
6	Innes 262 ...	·7	4·1	30 9	·84	168·9	0·76	0·8	2	I.	
9	Cape 1	8·3	5·0	40 40	·67	70·9	2·12	0·8	1	I.	
	"	"	"	"	·78	71·9	2·30	...	2	L.	
11	C Z. 1ʰ 152 ...	8·3	7·2	45 59	·67	70·5	2·86	0·2	1	I.	
	" ...	"	"	"	·86	68·3	3·17	...	2	L.	
New	Cape 26 ... (C.Z. 1ʰ 176) ...	8·7	8·0	49 48	1899·8	50 ±	1 ±	0·3	1	I.	Discovered at the transit circle by Mr. W. H. Cox.

Ref. Cat.	Star.	Mag.	1900. R.A. h m	1900. S.D. ° ′	Epoch.	Angle. °	Dist. ″	Diff. of Mags.	No. of Nights.	Obs.	Remarks.
13	Innes 27	7·3	1 11·6	69 21	1900·51	197·2	1·03	0·5	3	I.	Slight evidence of direct motion, but in κ Toucani, which is connected with this system, the motion is retrograde.
	"	"	"	"	·70	201·5	0·94	...	1	L.	
14	κ Toucani ...	4·9	12·4	69 24	·51	351·8	5·31	...	3	I.	
	" ...	"	"	"	·70	353·3	5·18	...	2	L.	
15	Innes 50	9·0	12·7	37 48	·85	144·3	0·85	1·0	2	I.	
22	*h* 3430	6·8	16·5	57 52	1899·95	237·0	2·85	...	2	I.	Companion deep yellow. Angle decreasing slowly.
26	Innes 263 ...	7·2	19·0	70 14	1900·37	60·5	0·74	0·2	2	I.	
	" ...	"	"	"	·72	63·0	0·84	...	1	L.	
New	Harvard (Lac. 388)	7·0	19·2	41 28	·86	240·5	4·47	4·3	2–1	I.	A yellow 4, B bluish. p.m. of A is $\alpha = [-0^s.01]$. $\delta = -0''.08$.
31	Innes 264 AB	8·0	27·6	53 53	·43	121·2	0·51	0·2	2–1	I.	
	" AB, C	"	"	"	·44	6·6	39·3	3·5	2	I.	
33	Innes 51	7·0	30·1	46 12	·85	13·0	1·77	2·9	2	I.	A yellowish 3, B bluish. p.m. of A = 0″·118 towards 31°·9.
35	τ Sculptoris ...	5·7	31·5	30 25	·89	94·2	1·96	...	2	L.	
37	*p* Eridani ...	5·3	36·0	56 42	·38	223·5	7·73	...	2	L.	
38	λ 15	7·8	36·4	22 13	·86	313·2	2·85	...	1	L.	
48	Innes 52	8·5	43·5	44 28	·86	181·2	0·65	0·4	1	I.	
55	χ Eridani ...	3·6	52·1	52 6	1899·96	197·6	6·24	...	2–1	I.	Common p.m.
56	*h* 3475	6·4	52·1	60 48	1900·11	49·6	2·61	...	1	I.	Slow increase in angle.
	"	"	"	"	·71	52·3	2·49	...	2	L.	
57	Cape 2	9·0	52·5	42 51	·68	94·8	3·28	0·5	2	L.	

Ref. Cat.	Star.		Mag.	1900. R.A.	1900. S.D.	Epoch.	Angle.	Dist.	Diff. of Mags.	No. of Nights.	Obs.	Remarks.
				h m	° ′		°	″				
61	Innes 265 ...	...	8·0	1 56·8	44 19	1900·86	25·4	0·79	0·7	1	I.	
5	*h* 3485 ...	...	8·1	2 7·8	49 48	·76	140·5	4·13	...	2	L.	Fixed.
7	Innes 266	...	7·6	10·4	66 37	·41	162·0	3·20	...	2	I.	A yellow, B blue.
12	*h* 3497 ...	AB	5·4	16·7	56 24	1899·96	81·5	33·3	5·1	1	I.	In *Ref. Cat.* delete "Harvard." No change since *h*.
	"	AC	"	"	"	·96	318·8	69·5	7·6	1	I.	New.
13	Innes 147	...	7·7	17·9	48 46	1900·41	339·8	1·62	...	2–1	I.	
	"		"	"	"	·70	Not seen double			1	L.	
24	Innes 53 ...	...	9·6	35·6	40 24	·10	331·0	4·09	...	1	I.	
	"		"	"	"	·86	330·4	3·54	...	1	L.	
New	Cape 27 (Lac. 1884)		7·9	39·1	88 50	·99	204·3	7·46	2·0	1–2	I.	Found by Mr. G. F. Johns on photo plates. It is somewhat surprising that such an easy pair should so long have escaped notice.
31	Innes 267	...	8·0	41·8	41 39	·40	24·7	2·04	...	2	I.	
32	Innes 28 ...	...	8·5	42·1	67 42	1899·96	Single	...	...	1	I.	The only pair near here is C.G.A. 2996+7 ($2^h\ 43^m{\cdot}6 - 67°\ 25'$).
35	C.Z. 2^h 1201	AB	9·0	44·3	60 34	1900·01	251·3	0·99	...	1	I.	Innes 268.
	"	AB, C	"	"	"	·01	215·4	21·1	...	1	I.	*h* 3534.
40	γ_2 Fornacis	...	5·6	45·6	28 21	·72	Single	...	...	1	L.	
43	Cordoba (6)	...	8·5	47·3	45 39	·40	181·2	3·67	0·2	2	I.	
46	Innes 148 ...	...	7·6	52·3	63 25	·43	7·9	5·04	...	2	L.	
47	Cordoba (7)	...	8·0	52·7	39 51	·40	183·5	3·40	0·3	2	I.	
48	Innes 149	...	9·4	52·8	23 47	·10	260·2	7·28	1·6	1	I.	

Ref. Cat.	Star.		Mag.	1900. R.A. h m	1900. S.D. ° ′	Epoch.	Angle. °	Dist. ″	Diff. of Mags.	No. of Nights.	Obs.	Remarks.
50	θ Eridani	...	3·1	2 54·5	40 42	1900·79	84·9	8·21	...	2	L.	
53	*h* 3549 ...	...	9·4	59·2	38 27	·10	277·2	5·96	...	1	I.	
4	Cape 3 ...	...	9·2	3 4·5	42 54	·06	249·8	2·61	...	1	I.	
5	Innes 54 ...	...	8·7	5·0	41 45	·06	132·6	1·23	0·5	1	I.	
10	P. III. 19	AB	5·9	8·9	44 48	·01	182·6	0·97	0·7	1	I.	AB yellowish.
	,,	AC	,,	,,	,,	·01	210·7	3·47	...	1	I.	C bluish.
	,,	BC	,,	,,	,,	·01	220·4	2·65	...	1	I.	
New	Innes 341 (O.A. 2179)		8·5	13·6	19 26	·8	10 ±	1·3 ±	1·2	1	I.	Found with the 7-in. refractor.
20	Innes 56 ...	...	8·5	15·1	43 0	·50	256·4	3·36	2·7	2	I.	
21	Innes 150	...	8·2	15·9	63 26	1899·96	357·7	4·08	2·0	2	I.	
23	Innes 151	...	8·2	18·7	41 41	1900·95	160·4	1·23	0·3	2	I.	Both white.
27	Innes 57 ...	...	9·0	24·0	59 38	·48	210·8	2·38	1·0	2	I.	
28	Cordoba (χ_3 Fornacis)		6·6	24·3	36 12	·95	249·1	6·30	4·1	2	I.	Small star reddish. In *Ref. Cat.* delete Innes 58. Noted dpl. 6½, 10 in Uranometria Argentina.
61	Innes 269	AB	7·3	58·7	54 41	·02	80·0	3·55	...	2–1	I.	
	,,	,,	,,	,,	,,	·03	78·5	3·99	...	1	G.	
	,,	,,	,,	,,	,,	·03	75·4	...	...	1	L.	
	,,	AC	,,	,,	,,	·03	196·0	27·8	4·7	1	I.	New.
	,,	,,	,,	,,	,,	·03	195·4	27·8	...	1	L.	
[illegible]	Russell 38	...	6·4	4 0·9	85 34	·08	245·0	2·31	...	1	L.	

Ref. Cat.	Star.		Mag.	1900. R.A. h m	1900. S.D. ° ′	Epoch.	Angle. °	Dist. ″	Diff. of Mags.	No. of Nights.	Obs.	Remarks.
4	Innes 152	...	7·6	4 1·2	35 43	1900·10	68·0	0·92	0·0	2–1	I.	
6	Innes 153	...	7·1	4·4	33 7	·55	339·5	0·83	0·0	2	I.	Both white.
12	υ_4 Eridani	...	3·8	14·1	34 2	·06	Single	...	...	2	I.	Considered double with the 7-in. (Innes 270).
21	Innes 271	...	7·5	18·5	43 1	·09	148·1	2·45	...	2	I.	*h* 3646.
22	Lac. 1435	A, BC	7·2	18·6	41 27	·03	137·2	38·3	...	1	I.	*h* 3646.
	"	"	"	"	"	·03	137·0	37·6	...	1	L.	
	"	BC	"	"	"	·51	191·3	1·24	1·0	2–1	I.	Innes 272.
New	Innes 384 (P. IV. 81)		6·7	19·5	35 47	·55	187·0	18·8	7·1	2	I.	Found with the 18-in McClean refractor.
23	Σ 544 ...	...	8·2	19·9	8 59	...	...	...	...	...	I.	In note in *Ref. Cat.* for "pr." read "f." (R.A. 4h 19m 54s).
26	Innes 59	AB	6 6	21·2	34 59	·09	198·0	42·4	3·4	1	I.	
	"	BC	"	"	"	·54	281·3	4·04	1·5	2	I.	
32	Innes 154	...	7·5	27·6	35 59	·55	318·5	0·61	0·1	2–1	I.	
New	Cape 28		9·1	34·1	50 21	1899·9	300 ±	3 ±	0·7	1	I.	Discovered with transit circle by Mr. J. A. J. Pead.
39	*h* 3672 ...	...	8·3	35·0	35 30	1900·54	300·2	4·48	0·7	2	I.	
43	Innes 60 ...	...	9·0	38·1	45 54	·54	96·0	2·72	0·2	2	I.	
52	Cordoba (11)	...	8·0	46·7	39 21	·58	51·8	3·91	...	2	I.	Also seen at Madras in 1865.
New	Innes 342 (Lac. 1637)	...	7·5	47·4	54 4	·22	176·5	1·11	0 6	1	I.	Found with the 18-in. McClean telescope.
"	Innes 343 (Lac. 1641)	...	7·8	47·7	54 37	·22	45·3	2·59	3·7	1	I.	Found with the 18-in. McClean telescope.

Ref. Cat.	Star.	Mag.	R.A. 1909 h m	S.D. 1909 ° ′	Epoch.	Angle. °	Dist. ″	Diff. of Mags.	No. of Nights.	Obs.	Remarks.
54	*h* 3699	7·7	4 47·7	45 50	1900·13	142·6	18·1	4·5	2	I.	No change in angle; *h* has 5″ ±.
56	Innes 273 ...	9·0	48·1	45 6	·54	350·6	1·27	0·1	2	I.	
61	*h* 3707	9·2	51·5	59 55	·17	269·0	8·79	3·5	1	I.	No nebula seen.
New	Innes 344 (C.Z. 4h 1849) ...	8·5	54 2	51 36	·60	21·5	1·80	2·3	2	I.	Found with the 18-in. McClean telescope.
1	Innes 274 ...	8·0	5 0 3	50 56	·03	257·0	3·27	...	1	G.	
	„ ...	„	„	„	·03	257·9	3·20	...	1	I.	
	„ ...	„	„	„	·05	257·7	3·18	...	2	L.	
12	κ Leporis ...	4·4	8·6	13 4	·12	359·9	2·54	...	1	L.	
14	Rigel A, BC	0·3	9·7	8 19	·18	202·9	9·36	...	1	L.	
19	Howe (C.Z. 5h 381)	8·3	11·6	29 37	·07	237·2	2·46	...	1	L.	
22	Cordoba (13) ...	8·8	14·0	27 36	·21	93·8	3·34	0·2	1	I.	
30	Peters (Bradley 757) ...	7 2	18·8	0 58	·10	167·1	2·16	...	1	L.	
34	Innes 275 ...	8·2	19·9	36 46	·15	1·7	1·62	0·5	2	I.	
New	Innes 345 (θ Pictoris) ...	6·3	22·5	52 24	·60	199·2	0·43	0·6	2	I.	Found with the 18-in. McClean telescope. As a wide pair this is Dunlop 20. p.m. in α uncertain, in δ = −0″·12.
New	Innes 346 (P.V. 122) ...	5·9	23·9	41 2	1899·9	180 ±	20 ±	6·1	1	I.	Found with the 18-in. McClean telescope.
40	*h* 3768	9·0	26·1	66 41	1900·21	...	...	...	1	I.	Nebula with star N.f. Nebula too diffused to be worth measuring as a double star.
1	Innes 276 ...	6·4	27·5	68 42	·59	212·9	0·56	0·3	2–1	I.	

Ref. Cat.	Star.		Mag.	1900. R.A.	1900. S.D.	Epoch.	Angle.	Dist.	Diff. of Mags.	No. of Nights.	Obs.	Remarks.
				h m	° ′		°	″				
43	Innes 62 ...	...	8·0	5 27·8	47 16	1900·59	176·9	0·81	0·4	2	I.	
52	Harvard (Lac. 1922)	...	6·6	29·6	64 0	·48	68·4	8·65	4·4	2	I.	
67	*h* 3784 ...	...	8·2	35·4	46 9	·14	60·7	5·71	...	1	L.	Common p.m. of 0″·48 towards 199°·5.
70	α Columbæ	...	2·7	36·0	34 8	·06	358·0	11·6	9·3	1	I.	The measure differs considerably from Prof. See's; on other occasions the companion was invisible.
	„	...	„	„	„	·32	Not seen		...	1	I.	
New	Innes 347 (Lac. 2022)	...	8·0	36·3	75 18	·11	127·2	8·99	3·0	1	I.	Found with the 18-in. McClean refractor.
72	Innes 277	...	8·0	36·6	71 12	·04	189·9	3·94	...	2	I.	A yellowish, B bluish.
77	Innes 278	...	8·5	42·6	68 45	·11	170·0	1·06	...	1	I.	
81	*h* 3802 ...	...	8·1	43·4	55 46	·05	307·8	8·05	...	1	L.	
84	Jacob (3)...	...	5·8	45·0	14 31	·12	179·6	2·57	...	1	L.	
86	Innes 63	AB	7·1	45·7	48 57	·08	11·5	1·45	...	2	I.	
	„	AC	„	„	„	·08	211·4	31·8	5·0	2	I.	A 10ᵐ star S.f.
New	Innes 348 (O.A. 4412)		9·0	49·0	29 3	·3	80 ±	2·5 ±	1·5	1	I.	Found with the 7-in. refractor.
89	Innes 64	AB	5·6	49·1	37 39	·05	233·0	18·8	5·4	2	I.	
	„	AC	„	„	„	1899·98	16·1	44·9	5·9	1	I.	
95	Innes 155	AB	8·0	55·6	33 50	1900·25	18·4	1·70	...	2	I.	
	„	AC	„	„	„	·21	97·2	18·1	3·3	1	I.	New.
3	*h* 3834 ...	...	5·8	6 1·8	45 5	·14	225·8	4·06	...	1	L.	

Ref. Cat.	Star.		Mag.	1900. R.A. h m	1900. S.D. ° ′	Epoch.	Angle. °	Dist. ″	Diff. of Magr.	No. of Nights.	Obs.	Remarks.
9	Innes 280 (C.Z. vi. 263)		9·0	6 6·7	46 20	1900·08	278·0	8·70	2·5	2	I.	There is a very faint pair about 50″ N.f. Identification and note in Ref. Cat. erroneous.
	„	...	„	„	„	·10	276·5	·11	4·5	1	L.	
New	Innes 349 (Lac. 2198)	...	7·0	10·7	29·34	·32	41·4	5·82	4·0	1	I.	Found with the 7-in. refractor.
4*a*	Cape 23 ...	...	8·5	11·8	49·5	·28	62·7	...	...	1	I.	
23	Innes 281	...	8·7	17·8	44 45	·c9	6·6	6·37	...	2	I.	A yellow. The p.m. of the chief star is 0″·23 towards 90°·0.
28	Innes 282	...	7·7	21·7	50 29	·06	312·5	1·85	...	1	I.	
31	G Puppis ..	...	6·0	23·1	48 7	·08	132·6	1·42	...	3	I.	B is yellowish.
	„ ...	...	„	„	„	·12	136·2	...	...	1	L.	
New	Innes 350 (Lac. 2315)		7·5	26·0	45 43	·98	10·4	16·1	5·5	1	I.	Found on triple chart plate No. 5711.
40	*β* 754 ...	...	7·0	31·1	33 56	...	...	...	...	...	...	This pair has a common p.m. of 0 ·118 towards 312°·6.
47	Innes 5 ...	...	6·6	36·9	61 27	·23	274·3	2·85	2·5	2	I.	
51	Cordoba (15)	AB	8·7	38·7	37 54	·22	277·8	4·13	1·3	2	I.	
	„	AC	„	„	„	·22	149·3	19·4	3·3	2	I.	New.
53	Innes 283	...	8·0	39·4	42 28	·18	181·4	2·62	...	2	I.	
55	Innes 179	...	6·9	41·2	30 29	·18	225·2	4·45	...	2	I.	Prof. See's angle requires + 20°.
57	Innes 284	...	8·5	41·6	64 25	·10	233·6	5·84	...	2	I.	
58	*h* 3891 ...	...	6·0	41·7	30 51	·17	225·0	5·06	...	1	L.	Prof. See's angle requires + 20°.
	„	...	„	„	„	·18	223·0	5·06	...	2–1	I.	

Ref. Cat.	Star.		Mag.	1900. R.A. h m	1900. S.D. ° ′	Epoch.	Angle. °	Dist. ″	Diff. of Magz.	No. of Nights.	Obs.	Remarks.
New	Innes 351 (Lac. 2515)		6·9	6 42·5	71 40	1900·18	335·6	10·7	3·1	1	I.	Found with the 18-in. McClean telescope. Another *comes* $11^{m}\cdot3$ 20° ± 40″ ±.
59	Innes 180	AB	8·5	42·5	52 19	·48	332·4	0·95	1·1	2	I.	Both white.
	,,	AC	,,	,,	,,	·48	243·1	43·5	3·0	2	I.	New.
64	Innes 157	...	7·0	44·7	54 35	·18	348·3	1·43	...	1	I.	
73	Innes 159	...	6·4	47·1	45 20	·12	324·8	6·00	...	1	I.	A orange, B blue.
75	Cordoba (16)	...	8·4	48·8	35 10	·17	110·4	2·89	...	1	L.	
83	Innes 65 ...	...	6·3	53·7	35 23	·01	184?	...	...	1	I.	Perhaps elongated.
	,,	...	,,	,,	,,	·06	184·9	0·3 ±	...	1	I.	In contact.
	,,	...	,,	,,	,,	·98	192·6	0·25 ±	...	1	I.	Elongated. Yellow 3.
10	Innes 184	AB	8·0	7 7·8	60 25	·11	175·9	0·86	0·4	3	I.	
		AC				·11	339·8	24·6	3·3	2	I.	New.
11	Hargrave 9	...	7·5	7·9	56 12	·38	221·6	1·8 ±	...	1	I.	
13	*h* 3941 ...	...	6·9	8·0	60 13	·11	302·0	1·22	0·3	3	I.	No certain change.
	Harvard (Lac. 2735)		6·0	11·1	63 1	·28	164·9	0·5 ±	...	1	I.	Bailey gives 1894·37 157°·0 0″·50 Δm = 0·3 2n.
24	τ Canis Majoris ...		4·6	14·6	24 46	·20	89·2	8·37	...	2	L.	
25	Innes 7 ...	...	7·3	14·6	46 49	·25	207·5	1·06	...	4·2	I.	Com. p.m. = 0″·588 towards 341°·7. Change of angle 7° in four years.
26	*h* 3949 ...	...	7·3	14·7	30 37	·20	77·5	2·94	...	2	L.	Very slow increase in angle.
27	Jacob (4) ...	...	9·1	15·0	36 35	·20	211·8	2·86	...	2	L.	Fixed.
28	Lalande 53	...	7·6	15·1	21 52	·06	345·4	3·97	...	1	L.	Very slow decrease in angle.

Ref. Cat.	Star.	Mag.	1900. R.A. h m	1900. S.D. ° ′	Epoch.	Angle. °	Dist. ″	Diff. of Mags.	No. of Nights.	Obs.	Remarks.
8*a*	Innes 312 ...	7·7	7 18·7	75 41	1900·27	169·9	1·14	0·1	1	I.	
38	λ 78	7·7	18·9	25 35	·08	288·5	2·16	1·8	1	I.	A remarkable object, very red. C = 9·0 and D = 10·0 also seen.
40	Lal. 14480 (β 199) AB	7·3	20·8	20 59	·10	21·1	2·11	...	1	L.	
	Lal. 14480 (Hough) AC				·10	116·4	7·06	...	1	L.	C = 13^{m}·0.
New	Innes 352 (C.Z. 7^{h} 1526)	8·5	22·4	37 57	·29	20 ±	0·5 ±	...	1	I.	Found with the 7-inch.
47	Σ 1104	6·8	24·8	14 47	·10	330·9	2·14	...	1	L.	
51	*h* 3996	7·6	27·8	84 17	·08	253·8	16·0	2·4	1	I.	The p.m. is very small. *h* has 248°·4.
52	Howe 7	8·6	29·8	23 29	·10	204·4	1·85	...	1	L.	
54	Cordoba 70 (Lal. 14834)	7·0	31·1	2 56		Single		...	4	I.	This star was observed double at Cordoba on one night when meridian places of both components were secured. The pair seen here in 1898 is 2 min. pr. and is BD − 2° No. 2180 mag. 9·0, measured by L. as follows:—1900·17 148°·5 7″ 54 1n.
55	Cordoba 71 (Bris. 1669)	7·7	31·1	66 58	·33	194 6	3·91	2·3	1	I.	
New	Innes 353 (Lac. 2915)	7·4	36 5	43 3	1899·9	45 ±	1 ±	0·5	1	I.	Found with the 7-inch. The p.m. is very small.
65	*h* 3997	6·1	37·4	74 3	1900·28	110 3	2·33	...	1	I.	Angle and distance increasing.
New	Innes 354 (C Z. 7^{h} 2786)	7·5	39·4	42 20	1899·9	135 ±	1 ±	...	1	I.	Found with the 7-inch. The p.m. is nil.

Ref. Cat.	Star.	Mag.	1900. R.A. h m	1900. S.D. ° ′	Epoch.	Angle. °	Dist. ″	Diff. of Mags.	No. of Nights.	Obs.	Remarks.
12	O.Stone(O.A.8124)	8·2	8 5·5	26 50	1900·22	261·2	3·33	...	2	L.	
18	Innes 192 ...	7·7	8·7	68 42	·18	174·7	2·04	...	1	I.	
37	„ 9	6·8	15·9	73 30	·18	312·4	...	0·1	1	I.	No third star seen.
41	B Velorum ...	4·8	19·5	48 10	·18	141·5	1·23	1·0	1	I.	
...	Cordoba (Bris. 2035)	7·5	24·5	40 55	·4	110 ±	5 ±	2·8	1	I.	C.Z. 8h 1971 mag. 9·0 is 2 sec. f. 16″ N.
50	Innes 195 ...	6·9	30·7	37 16	·25	42·4	2·31	...	2	L.	
New	„ 355 ...	8·2	31·8	20 43	·3	50 ±	0·8 ±	1·0	1	I.	Found with the 7-inch.
15*a*	„ 314 ...	6·7	35·6	36 15	·38	239·4	0·96	2·5	1	I.	
57	Harvard (Lac. 3467)	6·5	35·9	52 44	·18	294·4	22·3	...	1	I.	
					·27	294·5	cloud	...	1	L.	
...	*h* 4126 (Lac. 3476)	6·0	37·1	52 42	·26	29·8	16·7	...	2	L.	See also 16*a* in Ref. Cat.
65	δ Argûs AB ...	2·0	41·9	54 21	·19	173·2	2·46	...	4	I.	B orange yellow.
	„ „ ...	„	„	„	·28	175·3	2·05	...	2	L.	Common proper motion.
	„ AC ...	„	„	„	1899·99	62·0	69·5	...	1	I.	There is a 12m·0 star 240° ± 70″ ±.
	„ „ ...	„	„	„	1900·30	62·0	69·3	...	2	L.	
New	Innes 356 (C.P.D. – 54°1795)	10·0	42·6	54 18	1899·99	297·1	3·04	1·0	1	I.	Found with the 18-inch McClean telescope. 36s. f. δ Argûs.
69	Innes 70	7·0	44·0	38 34	1900·29	114·4	1·19	2·5	1	I.	
...	*h* 4148	8·3	47·9	53 44	·26	111·4	...	...	1	L.	
19*a* (20*a*)	Innes 317 ...	8·5	51·6	43 5	·29	303·4	1·86	1·2	1	I.	No. 19*a* should be struck out (error of copying).

Ref. Cat.	Star.	Mag.	1900. R.A. h m	1900. S.D. ° ′	Epoch.	Angle. °	Dist. ″	Diff. of Mags.	No. of Nights.	Obs.	Remarks.
89	H Velorum ...	4.7	8 53.3	52 20	1900.23	343.6	2.65	...	1	L.	
	" ...	"	"	"	.30	340.7	2.56	...	1	I.	Fixed in angle, distance perhaps decreasing. B bluish.
90	Cordoba 20 (Lac. 3615)	7.5	53.5	42 52	.31	45.0	3.03	2.5	2	I.	
91	Gilliss 104 (Lac. 3648)	7.0	56.8	49 10	.31	305.1	8.97	2.7	2–1	I.	A yellow, B blue. And Innes 71 = &c. should be struck out. An $11^m.0$ is N. pr. and an $11^m.5$ N. f.
93	Innes 287 ...	8.0	55.1	73 40	.33	241.6	1.94	2.0	2–1	I.	
...	*h* 4164 (Lac. 3666)	7.5	55.8	65 49	.32	145.5	10.4	...	1	I.	The companion is C.Z. 8^h 4488 mag. 9.2.
21*a*	b_2 Carinæ ...	5.2	57.0	58 42	.31	200	29.1	...	3–2	I.	
	" ...	"	"	"	.33	18.7	29.2	...	1	L.	
New	Innes 357 (O.A. 9263)	8.4	57.6	23 21	.3	175 ±	0.6 ±	...	1	I.	Found with the 7-inch.
96	*h* 4165	5.4	58.6	51 48	.30	99.2	1.20	...	1	I.	Slow increase in angle.
97	*h* 4167	8.9	58.8	65 57	.31	25.2	4.35	...	2	I.	Fixed, *h* has 25°.1.
2	Howe 10	7.7	9 2.1	31 12	.23	307.9	3.08	...	2	L.	
3	*h* 4178	6.9	2.1	57 27	.31	165.6	3.44	3.6	2	I.	No change. Many faint stars about, the closest $= 12^m$ is f, a little N.
4	Innes 196 ...	8.5	2.4	49 45	.29	174.3	0.69	...	1	I.	
"	" ...	"	"	"	.30	171.3	0.80	...	1	L.	
8	Cordoba 21 (C.Z. 9^h 448)	8.3	6.3	43 46	.33	44.6	2.47	...	1	I.	

Ref. Cat.	Star.		Mag.	1900. R.A. h m	1900. S.D. ° ′	Epoch.	Angle. °	Dist. ″	Diff. of Magr.	No. of Nights.	Obs.	Remarks.
9	Innes 288	...	8·2	9 5·9	74 21	1900·34	254·0	0·76	...	2	I.	
11	„ 169	...	7·2	7·3	42 51	·34	Single	...	...	2	I.	Original record referred to. Found on the "best night I ever saw." No p.m.
22a	„ 319	...	9·1	10·4	82 37	·18	84·1	4·79	1·5	1	I.	Surrounded by 4 or 5 small stars, the closest almost due S.
New	Innes 358 (Lac. 3811)		5·4	15·9	68 16	·34	131·8	18·2	6·6	1	I.	Found with the 18-in. McClean telescope. p.m. is $\alpha = -0^s{\cdot}016$, $\delta = 0''{\cdot}0 \pm$.
27	Lac. 3846	AB	5·4	17·6	74 28	·34	266·7	0·3 ±	1·0	1	I.	Innes 12, but rejected in the Ref. Cat., as I could not see it double with the 7-in. Estimate in 1894 = 290° ±.
„	„	AB, C	„	„	„	·34	340·7	7·05	4·6	1	I.	*h* 4206.
31	I Velorum	BC	9·4	23·1	52 57	·34	35·4	3·10	1·0	1	I.	
32	Innes 199	...	8·5	23·4	69 59	·34	318·1	2·60	...	1	I.	
40	ψ Argûs ...	...	3·5	26·8	40 2	·30	292·8	0·76	...	4–1	I.	Weighted mean. Found by Dr. Copeland. Change at present 12° ± p. an.
41	Innes 31 ...	...	9·2	27·9	56 33	·34	155·4	3·21	...	1	I.	Also an $11^m{\cdot}0$ N. pr., an $11^m{\cdot}0$ S. pr. and a $12^m{\cdot}5$ S. f.
47	*h* 4220 ...	...	5·3	30·2	48 34	·24	207·4	2·38	...	5	L.	Very slow increase in angle.
New	Innes 359 (Lac. 3977)		8·0	33·8	67 46	·29	172·8	1·69	3·0	1	I.	Found with the 18-in. McClean telescope.
New	Innes 360 (G.P.Z. 6364)		8·9	33·9	66 50	·29	184·8	4·92	1·0	1	I.	Found with the 18-in. McClean telescope.
75	Innes 291	...	7·2	59·3	70 15	·22	323·7	1·18	3·0	1	I.	

Ref. Cat.	Star.		Mag.	R.A. 1900. h m	S.D. ° ′	Epoch.	Angle. °	Dist. ″	Diff. of Mags.	No. of Nights.	Obs.	Remarks.
14	Innes 13	AB	6·4	10 7·0	68 12	1900·26	146·7	0·90	0·2	2	I.	
”	”	”	”	”	”	·28	149·3	1·16	...	2	L.	
”	”	AC	”	”	”	·22	39·9	35·1	3·3	1	I.	
”	”	”	”	”	”	·27	40·3	...	...	1	L.	
17	Howe 13 ...	...	8·3	10·3	36 9	·28	307·2	3·09	...	3–2	L.	
18	*h* 4310 ...	...	7·3	10·4	83 36	·31	272·4	3·57	...	2	L.	
New	Innes 361 (C.Z. 10h 707)		8·9	10·6	47 9	·29	150 ±	4 ±	2·1	1	I.	Found with the 7-in. telescope.
35	Cordoba 23 (C.Z. 10h 1352)		7·8	19·1	65 11	·22	156·9	4·09	2·5	1	I.	
			”	”	”	·30	157·5	3·86	...	2	L.	
37	Innes 209	...	7·5	20·0	38 4	·44	137·8	1·11	...	1	I.	
38	” 210	...	7·7	23·4	38 12	·44	235·4	...	2·5	1	I.	
44	*h* 4329 ...	...	5·1	27·5	53 12	·37	83·0	31·2	...	2	L.	Change due to p.m. of the chief star.
62	t_2 Carinæ	...	4·7	35·0	58 40	·41	20·1	14·7	...	1	L.	
66	Cordoba 25 (C.Z. 10h 2704)		8·5	38·2	44 44	·41	224·3	2·98	...	1	L.	
73	Σ 1470 ...	...	8·5	41·2	5 14	·30	12·5	1·51	...	2	L.	
74	μ Argûs ...	...	2·8	41·5	48 54	·36	61·7	2·73	...	1	I.	Very slow increase in angle probable.
”	” ...	...	”	”	”	·41	61·5	2·21	...	1	L.	
76	40 Sextantis	...	6·7	44·2	3 30	·30	3·0	2·27	...	2	L.	
77	δ_1 Chamæleontis ...		5·5	44·3	79 55	·36	63·9	0·40	0·2	1	I.	

Ref. Cat.	Star.		Mag.	1900. R.A. h	m	S.D. °	′	Epoch.	Angle. °	Dist. ″	Diff. of Mags.	No. of Nights.	Obs.	Remarks.
78	*h* 4373 ...	...	8·9	10	44·4	40	55	1900·36	344·0	10·9	...	1	I.	A yellow. Movement.
84	Innes 306	...	9·0		51·5	47	3	·36	164·3	1·14	2·0	1	I.	The p.m. is very small.
89	Σ 1500 ...	...	7·3		54·9	2	56	·30	314·2	1·68	...	2	L.	
93	Innes 212	...	7·0		58·1	81	1	·36	145·9	0·72	0·1	1	I.	Both white.
12	*h* 4423 ...	...	6·4	11	11·8	45	20	·30	277·0	2·16	...	2	L.	
20	Cape 21 ...	...	9·1		19·5	47	25	·35	286·0	3 40	...	2	L.	
29	ω_1 Centauri	...	4·9		27·1	58	53	·48	125·8	...	...	1	L.	
42	Innes 34	AB	5 1		34·9	64	51	·32	233·0	39·4	...	1	L.	The p.m. is very small.
„	„	AC	„		„	„		·32	31·4	41·3	...	1	L.	
43	Innes 232	...	7·2		35·0	32	54	·30	162·8	2·27	...	2	L.	
46	*h* 4465 ...	...	5·0		36·7	31	57	·48	343·8	25·9	...	1	I.	
59	Innes 79 ...	...	7·8		49 8	41	50	·48	103·3	0·91	0·2	1	I.	
61	„ 80 ...	...	7·5		50 3	41	21	·48	106·9	1·46	0·0	1	I.	
3	η Crucis ...	...	4·3	12	1·7	64	3	·36	Not seen		...	1	I.	Harvard star 210° ± 30″.
8	Innes 216	...	7·5		4·6	51	14	·37	39·2	1·03	3·0	2	I.	Some faint stars near.
15	*h* 4505 ...	...	7·9		6·5	30	3	·36	269·4	9·86	...	1	I.	
„	„ ...	...	„		„	„		·48	269·1	10·6	...	1	L.	
19	D Centauri	...	5·4		8·8	45	10	·40	244·3	3·11	...	2	L.	Colours: Orange and bluish (I).
27	F Centauri	...	5·0		13·7	54	35	·38	87·2	35·9	7·0	1	I.	Angle perhaps 180° wrong, as W. H. Pickering gives 265° ±. Star too faint for good measures.

Ref. Cat.	Star.	Mag.	1900. R.A. h m	1900. S.D. ° ′	Epoch.	Angle. °	Dist. ″	Diff. of Mags.	No. of Nights.	Obs.	Remarks.
31	ζ_2 Muscæ ...	5·3	12 16·6	66 58	1900·43	131·6	32·6	5·2	2	I.	B is a red star.
33	Howe 21	7·6	17·4	33 0	·47	276·2	3·66	1·5	1	I.	
	”	”	”	”	·48	276·4	3·31	...	1	L.	
36	Innes 35 (C.Z. 12^h 1236)	8·5	21·4	76 7	1899·5	150 ±	2 ±	...	1	I.	Wrongly identified in Ref. Cat.
41	α Crucis	1 0	21·0	62 33	1900·07	117·6	4·95	...	1	L.	
45	Cape 12	7·0	22·7	61 12	·49	260·8	1·89	2·0	1	I.	Angle decreases 0°·5 per an.
59	Innes 296 ...	6·7	32·8	74 49	·52	273·9	...	...	1	I.	Very poor.
61	γ Centauri ...	2·4	36·0	48 25	·49	357·3	1·50	0·1	3–2	I.	Day observations. *h*'s angles require +180°, so that half the angular orbit has now been described. The period will, however, be over 150 years. Professor See gives 88 years, which is certainly too small.
66	Cordoba (27) ...	8·3	39·4	61 40	·51	189·6	5·00	1·5	1	I.	A orange, B bluish. Between two stars 11·0 and 11·5 mags.
67	ι Crucis	4·7	39·8	60 26	·36	34·6	26·9	...	1	I.	I's distance of 1896·6 referred to two fairly accordant single distances. The change is about accounted for by the p.m. of *ι Crucis*, viz. 0″·12 towards 150°, but the meridian observations are scanty and uncertain.
		”	”	”	·48	34·3	26·9	...	1	L.	
68	β Muscæ... ...	3·3	40·2	67 34	·36	341·0	1·33	...	3	I.	
	”	”	”	”	·40	346·0	1·60	...	3–1	L.	
New	Innes 362 (β Crucis)	1·7	41·9	59 9	·52	322·2	44·4	9·8	1	I.	Found with the 18-inch McClean refractor.

Ref. Cat.	Star.		Mag.	1900. R.A. h m	1900. S.D. ° ′	Epoch.	Angle. °	Dist. ″	Diff. of Magr.	No. of Nights.	Obs.	Remarks.
9	Innes 288	...	8·2	9 6·9	74 21	1900·34	254·0	0·76	...	2	I.	
11	„ 169	...	7·2	7·3	42 51	·34	Single	...	...	2	I.	Original record referred to. Found on the "best night I ever saw." No p.m.
22a	„ 319	...	9·1	10·4	82 37	·18	84·1	4·79	1·5	1	I.	Surrounded by 4 or 5 small stars, the closest almost due S.
New	Innes 358 (Lac. 3811)		5·4	15·9	68 16	·34	131·8	18·2	6·6	1	I.	Found with the 18-in. McClean telescope. p.m. is $\alpha = -0^{s}\cdot016$, $\delta = 0''\cdot0 \pm$.
27	Lac. 3846	AB	5·4	17·6	74 28	·34	266·7	0·3 ±	1·0	1	I.	Innes 12, but rejected in the Ref. Cat., as I could not see it double with the 7-in. Estimate in 1894 = 290° ±.
„	„	AB, C	„	„	„	·34	340·7	7·05	4·6	1	I.	*h* 4206.
31	I Velorum	BC	9·4	23·1	52 57	·34	35·4	3·10	1·0	1	I.	
32	Innes 199	...	8·5	23·4	69 59	·34	318·1	2·60	...	1	I.	
40	ψ Argûs ...	...	3·5	26·8	40 2	·30	292·8	0·76	...	4–1	I.	Weighted mean. Found by Dr. Copeland. Change at present 12° ± p. an.
41	Innes 31 ...	...	9·2	27·9	56 33	·34	155·4	3·21	...	1	I.	Also an $11^{m}\cdot0$ N. pr., an $11^{m}\cdot0$ S. pr. and a $12^{m}\cdot5$ S. f.
47	*h* 4220 ...	...	5·3	30·2	48 34	·24	207·4	2·38	...	5	L.	Very slow increase in angle.
New	Innes 359 (Lac. 3977)		8·0	33·8	67 46	·29	172·8	1·69	3·0	1	I.	Found with the 18-in. McClean telescope.
New	Innes 360 (G.P.Z. 6364)		8·9	33·9	66 50	·29	184·8	4·92	1·0	1	I.	Found with the 18-in. McClean telescope.
75	Innes 291	...	7·2	59·3	70 15	·22	323·7	1·18	3·0	1	I.	

Ref. Cat.	Star.		Mag.	R.A. 1900. h m	S.D. 1900. ° ′	Epoch.	Angle. °	Dist. ″	Diff. of Mags.	No. of Nights.	Obs.	Remarks.
14	Innes 13	AB	6·4	10 7·0	68 12	1900·26	146·7	0·90	0·2	2	I.	
„	„	„	„	„	„	·28	149·3	1·16	...	2	L.	
„	„	AC	„	„	„	·22	39·9	35·1	3·3	1	I.	
„	„	„	„	„	„	·27	40·3	...	...	1	L.	
17	Howe 13 ...	...	8·3	10·3	36 9	·28	307·2	3·09	...	3–2	L.	
18	*h* 4310 ...	...	7·3	10·4	83 36	·31	272·4	3·57	...	2	L.	
New	Innes 361 (C.Z. 10h 707)		8·9	10·6	47 9	·29	150 ±	4 ±	2·1	1	I.	Found with the 7-in. telescope.
35	Cordoba 23 (C.Z. 10h 1352)		7·8	19·1	65 11	·22	156·9	4·09	2·5	1	I.	
			„	„	„	·30	157·5	3·86	...	2	L.	
37	Innes 209	...	7·5	20·0	38 4	·44	137·8	1·11	...	1	I.	
38	„ 210	...	7·7	23·4	38 12	·44	235·4	...	2·5	1	I.	
44	*h* 4329 ...	...	5·1	27·5	53 12	·37	83·0	31·2	...	2	L.	Change due to p.m. of the chief star.
62	t_2 Carinæ	...	4·7	35·0	58 40	·41	20·1	14·7	...	1	L.	
66	Cordoba 25 (C.Z. 10h 2704)		8·5	38·2	44 44	·41	224·3	2·98	...	1	L.	
73	Σ 1470 ...	...	8·5	41·2	5 14	·30	12·5	1·51	...	2	L.	
74	μ Argûs ...	...	2·8	42·5	48 54	·36	61·7	2·73	...	1	I.	Very slow increase in angle probable.
„	„ ...	...	„	„	„	·41	61·5	2·21	...	1	L.	
76	40 Sextantis	...	6·7	44·2	3 30	·30	3·0	2·27	...	2	L.	
77	δ_1 Chameleontis ...		5·5	44·3	79 55	·36	63·9	0·40	0·2	1	I.	

Ref. Cat.	Star.		Mag.	1900. R.A.		1900. S.D.		Epoch.	Angle.	Dist.	Diff. of Mags.	No. of Nights.	Obs.	Remarks.
				h	m	°	′		°	″				
78	h 4373 ...	...	8·9	10	44·4	40	55	1900·36	344·0	10·9	...	1	I.	A yellow. Movement.
84	Innes 306	...	9·0		51·5	47	3	·36	164·3	1·14	2·0	1	I.	The p.m. is very small.
89	Σ 1500 ...	...	7·3		54·9	2	56	·30	314·2	1·68	...	2	L.	
93	Innes 212	...	7·0		58·1	81	1	·36	145·9	0·72	0·1	1	I.	Both white.
12	h 4423 ...	...	6·4	11	11·8	45	20	·30	277·0	2·16	...	2	L.	
20	Cape 21 ...	...	9·1		19·5	47	25	·35	286·0	3 40	...	2	L.	
29	ω_1 Centauri	...	4·9		27·1	58	53	·48	125·8	...	...	1	L.	
42	Innes 34	AB	5 1		34·9	64	51	·32	233·0	39·4	...	1	L.	The p.m. is very small.
,,	,,	AC	,,		,,	,,		·32	31·4	41·3	...	1	L.	
43	Innes 232	...	7·2		35·0	32	54	·30	162·8	2·27	...	2	L.	
46	h 4465 ...	...	5·0		36·7	31	57	·48	343·8	25·9	...	1	I.	
59	Innes 79 ...	...	7·8		49 8	41	50	·48	103·3	0·91	0·2	1	I.	
61	,, 80 ...	...	7·5		50 3	41	21	·48	106·9	1·46	0·0	1	I.	
3	η Crucis ...	...	4·3	12	1·7	64	3	·36	Not seen		...	1	I.	Harvard star 210° ± 30″.
8	Innes 216	...	7·5		4·6	51	14	·37	39·2	1·03	3·0	2	I.	Some faint stars near.
15	h 4505 ...	...	7·9		6·5	30	3	·36	269·4	9 86	...	1	I.	
,,	,, ...	...	,,		,,	,,		·48	269·1	10·6	...	1	L.	
19	D Centauri	...	5·4		8·8	45	10	·40	244·3	3·11	...	2	L.	Colours: Orange and bluish (I).
27	F Centauri	...	5·0		13·7	54	35	·38	87·2	35·9	7·0	1	I.	Angle perhaps 180° wrong, as W. H. Pickering gives 265° ±. Star too faint for good measures.

Ref. Cat.	Star.	Mag.	R.A. 1900. h m	S.D. 1900. ° ′	Epoch.	Angle. °	Dist. ″	Diff. of Mags.	No. of Nights.	Obs.	Remarks.
31	ζ_2 Muscæ ...	5·3	12 16·6	66 58	1900·43	131·6	32·6	5·2	2	L.	B is a red star.
33	Howe 21	7·6	17·4	33 0	·47	276·2	3·66	1·5	1	I.	
	”	”	”	”	·48	276·4	3·31	...	1	L.	
36	Innes 35 (C.Z. 12h 1236)	8·5	21·4	76 7	1899·5	150 ±	2 ±	...	1	I.	Wrongly identified in Ref. Cat.
41	α Crucis	1·0	21·0	62 33	1900·07	117·6	4·95	...	1	L.	
45	Cape 12	7·0	22·7	61 12	·49	260·8	1·89	2·0	1	I.	Angle decreases 0°·5 per an.
59	Innes 296 ...	6·7	32·8	74 49	·52	273·9	...	...	1	I.	Very poor.
61	γ Centauri ...	2·4	36·0	48 25	·49	357·3	1·50	0·1	3–2	I.	Day observations. *h*'s angles require +180°, so that half the angular orbit has now been described. The period will, however, be over 150 years. Professor See gives 88 years, which is certainly too small.
66	Cordoba (27) ...	8·3	39·4	61 40	·51	189·6	5·00	1·5	1	I.	A orange, B bluish. Between two stars 11·0 and 11·5 mags.
67	ι Crucis	4·7	39·8	60 26	·36	34·6	26·9	...	1	I.	I's distance of 1896·6 referred to two fairly accordant single distances. The change is about accounted for by the p.m. of *ι Crucis*, viz. 0″·12 towards 150°, but the meridian observations are scanty and uncertain.
		”	”	”	·48	34·3	26·9	...	1	L.	
68	β Muscæ... ...	3·3	40·2	67 34	·36	341·0	1·33	...	3	I.	
	”	”	”	”	·40	346·0	1·60	...	3–1	L.	
New	Innes 362 (β Crucis)	1·7	41·9	59 9	·52	322·2	44·4	9·8	1	I.	Found with the 18-inch McClean refractor.

Ref. Cat.	Star.	Mag.	R.A. 1900. h m	S.D. 1900. ° ′	Epoch.	Angle. °	Dist. ″	Diff. of Mags.	No. of Nights.	Obs.	Remarks.
77	Harvard (Lac. 5303)	5·8	12 47·4	59 47	1900·24	Not found.			1	I.	
78	Innes 297 ...	8·3	48 2	51 44	·44	249·9	1·84	1·5	2	I.	
82	Harvard (Lac. 5321)	5·6	50·1	56 18	·45	314·8	29·4	4·9	2	I.	
87	Cordoba (28) ...	8·0	52·8	70 6	·48	269·7	4·13	...	1	L.	Fixed.
New	Innes 363 (C.Z. 12h 3166)	8·5	55·1	67 19	·5	190 ±	3 ±	1·2	1	I.	Found with the 7-inch refractor.
1	*h* 4566	6 6	13 0 3	77 55	·29	228·2	30·1	5·4	1	I.	
	,,	,,	,,	,,	·33	228·1	29 6	...	1	L.	
2	*f* Centauri ...	4·9	0·5	47 56	·31	78·0	11·9	...	2	I.	Companion reddish. Fixed.
	,,	,,	,,	,,	·33	80·5	11·8	...	1	L.	Companion not red. Fixed.
3	ξ_2 Centauri ...	4·4	1·1	49 22	·24	100·6	25·6	...	1	I.	Common proper motion.
	,,	,,	,,	,,	·33	100·5	25·0	...	1	I.	Common proper motion.
10	Harvard (Lac. 5409)	6·4	5·0	69 26	·43	279·5	30·8	4·6	2	I.	No nearer star seen.
11	Cordoba (72) ...	8·0	5·4	46 45	·24	276·4	3·43	...	1	I.	
	,,	,,	,,	,,	·35	277·7	3·55	...	1	L.	
1	Innes 310 ...	8·7	5·8	76 56	·43	37·6	2·11	1·2	2	I.	The brightest of neighbourhood.
26	J Centauri ...	4·6	16·2	60 28	·42	...	...	...	2	I.	Very rich region but no *comes* within 20″.
29	*h* 4580	6·6	17·1	48 2	·40	Single.			2	I.	Perhaps a suspicion of elongation 33° on one night. The p.m. is insensible.
	,, ...	,,	,,	,,	·33		,,		1	L.	

Ref. Cat.	Star.	Mag.	1900. R.A. h m	1900. S.D. ° ′	Epoch.	Angle. °	Dist. ″	Diff. of Mags.	No. of Nights.	Obs.	Remarks.
32	Cordoba (30) ...	7·0	13 19·1	51 19	1900·29	No double here.			2	L.	
New	Cape 32 (C.P.D. – 52° No. 6487)	8·4	20·1	52 46	·5	85° ±	3″ ±	1·0	1	L.	Found by Mr. J. A. J. Pead at the transit circle.
New	Innes 364 (C.Z. 13ʰ 1342)	8·7	24·2	68 36	·29	343·5	1·18	2·0	1	I.	A and B. Found with the 18-inch McClean refractor.
	„	„	„	„	·42	213·3	7·03	2·2	2	I.	A and C. Found with the 18-inch McClean refractor.
42	Innes 298 ...	7·2	25·2	68 43	·43	201·5	0·80	...	2	I.	Both yellow.
43	Russell 220 ...	9·0	25·4	57 55	·56	228·2	0·84	0·3	1	I.	
45	Hargrave 86 ...	7·5	25·8	61 50	·42	239·1	1·84	...	1	L.	
New	Innes 365 ...	6·5	30·4	61 11	·43	233·7	0·3 ±	0·5	2	I.	Pear-shaped. Found with the 18-inch McClean refractor. This is in the Ref. Cat. No. 50 of 13ʰ for *comites* noted at Arequipa. See *Harvard Annals*, vol. xxxii. pt. 2, for description of three companions at 20″, 20″, and 30″, the second being misprinted 2″·0. Correction due to Professor E. C. Pickering.
58	Cape 14 ...	8·5	32·4	41 53	·24	287·8	2·58	...	1	I.	
	„	„	„	„	·44	285·2	2·94	...	3	L.	
61	h 4598 ...	7·0	33·2	74 37	·56	47·1	13·1	3·5	1	I.	
68	Innes 223 ...	6·8	40·2	62 5	·38	320·2	9·05	2·7	1	I.	A very red, B blue.
	„	„	„	„	·45	319·1	9·39	...	2	L.	
69	M Centauri ...	4·6	40·3	50 56	·56	pr.	30″–40″	...	1	I.	
76	h 4616 ...	9·5	44·6	70 41	·56	348·7	4·19	1·0	1	I.	Fixed.

Ref. Cat.	Star.	Mag.	1900. R.A. h m	1900. S.D. ° ′	Epoch.	Angle. °	Dist. ″	Diff. of Mags.	No. of Nights.	Obs.	Remarks.
87	Russell 227 ...	6·6	13 49·8	53 39	1900·30	353·8	1·62	2·0	1	I.	Very slow increase in angle and distance.
	„	„	„	„	·48	354·3	1·75	...	1	L.	
89	Dunlop 151 ...	7·0	50·7	55 33	·50	20·4	14·2	...	2	L.	Rectilinear motion.
90	*h* 4630	8·2	50·9	65 9	·50	313·4	4·18	...	2	L.	Fixed.
91	*h* 4632	6·2	51·1	65 19	·50	14·3	6·47	...	2	L.	A faint *comes* 30″ 50° ±. This would seem to be the more distant of the stars noted by W. H. Pickering.
98	Innes 225 ...	7·2	54·2	62 28	·38	305·4	2·43	3·8	1	I.	Several very faint stars 30″ pr. Many stars within 1′.
2	θ Centauri ...	2·2	14 0·8	35 53	·42	No close comp.			1	L.	
13	Harvard (Lac. 5850)	5·2	8·0	56 37	·58	169·5	34·5	5·8	1	I.	An $11^m·5$ star is more distant S pr.
14	„ (Lac. 5846)	5·9	8·8	66 7	·56	307·2	23·6	6·1	1	I.	
New	Innes 366 (R Centauri)	var.	9·4	59 27	·57	217·6	28·0	mag. 12·2	2	I.	Found with the 18-inch McClean refractor whilst looking for the Harvard companion. The Harvard companion is 355° 30″ 12^m. This is identical probably with a small pair $10^m·5$ and $11^m·5$ 35″ N. pr. R Centauri.
32*a*	C.Z. 14^h 602 AB	8·7	11·3	68 10	·56	42·9	52·6	1·5	1	I.	The differences of magnitude recorded would indicate that the catalogue magnitudes are wrong.
„	C.P.D. −68° 2106 BC	9·0	„	„	·56	220·6	8·57	0·5	1	I.	
36	Harvard (Lac. 5934)	6·3	20·8	45 41	·48	143·4	27·0	5·0	1	I.	Another $11^m·5$ 195° ± 30″ ±.
41	„ (Lac. 5950)	5·5	23·7	49 4	·54	18·0	22·3	6·0	2–1	I.	Another *comes* three times as far in opposite direction. These observations do not accord with Arequipa results, viz. 290° 25″ $13^m·5$.

Ref. Cat.	Star.	Mag.	R.A. 1900. h m	S.D. 1900. ° ′	Epoch.	Angle. °	Dist. ″	Diff. of Mags.	No. of Nights.	Obs.	Remarks.
54	Harvard (Lac. 5995)	5·3	14 29·8	45 49	1900·48	100 ±	40 ±	6·7	1	I.	
55	Cordoba (36)	8·4	30·1	59 55	·42	144·7	4·02	0·9	2	I.	
New	Innes 367 (C.Z. 14^h 1895)	8·0	31 6	64 17	·36	355·3	4·63	3·0	2	I.	Found with the 18-inch McClean refractor.
59	*a* Centauri ...	0·2	32·8	60 25		Given separately.					
63	*a* Circini ...	3·4	34·4	64 32	·42	236·8	16·0	...	2	I.	Very slow decrease in angle. See's angle in error?
73	Harvard (Lac. 6039)	5·2	37·4	62 27	·52	64·0	36·5	4·3	2	I.	
New	Innes 368 (C.Z. 14^h 2255)	9·2	37·6	62 25	·49	2·9	3·48	1·0	2	I.	Closely N. f. the preceding star. Found with the 18-inch McClean telescope.
77	Innes 235 ...	7·2	39·2	68 6	·49	111·2	0·69	0·7	2	I.	
78	*h* 4696	7·2	39·4	44 27	·51	...	...	...	1	I.	No close comp. A 12^m star 50″ ± pr. p.m. small.
80	*m* Hydræ ...	5·1	40·2	25 1	·36	129·7	9·02	...	1	I.	Both stars round.
	„ ...	„	„	„	·48	130·0	8·97	...	1	L.	
81	Harvard (Lac. 6074)	6·5	40·2	51 47	·51	290·6	39·5	5·0	1	I.	A $10·5^m$ star is N. f.
82	„ (Lac. 6059)	6·1	40·3	66 10	·48	Nil	...	...	1	I.	Bris. 5037 = $8^m·2$ which is in the field has an 11^m *comes* 150° ± 30″ ±.
New	Innes 369 (C.Z. 14^h 2441)	8·5	40·4	66 10	·49	241·7	2·68	2·3	2	I.	Closely following Lac. 6059. Found with 18-inch McClean telescope. See also preceding entry.
88	Innes 236 ...	5·6	43·2	72 47	·40	103·2	1·59	3·4	2–1	I.	A yellowish, B bluish.
	„ ...	„	„	„	·51	102·3	1·65	...	1	L.	

Ref. Cat.	Star.	Mag.	1900. R.A. h m	1900. S.D. ° ′	Epoch.	Angle. °	Dist. ″	Diff. of Mags.	No. of Nights.	Obs.	Remarks.
92	*h* 4707	7·7	14 45·8	66 0	1900·50	120·2	0·63	0·1	2	I.	This angle is diminishing and not increasing, as was inferred from *h*'s observations. The change in 65 years is 100° or 460°.
36*a*	Innes 327 ...	8·0	48·6	66 28	·53	77·1	3 10	3·0	2–1	I.	
113	Cape 15	7·1	56·4	71 47	·50	43 2	1·73	...	2	L.	
116	π Lupi	3·8	58·3	46 40	·42	86·4	1·18	...	2	I.	Continued "arrest of motion."
	B.D. −21° 4019	„	58 5	21 42	·4	320 ±	3 ±	0·4	1	I.	Both stars observed in the 2nd Washington Cat.
2	T Triang. Aust. ...	var.	15 0·4	68 20	·63	41·1	41·5	mag. 10·2	1	I.	A 10^m·7 star 311° ± 55″ ±.
9	*h* 4735	7·4	4·8	60 1	·54	33·4	6·92	3·1	2	I.	
11	*h* 4731	9·3	5·2	77 30	·51	249·6	3·12	...	1	L.	
	„	„	„	„	·63	252·0	3·20	0·7	1	I.	Two very faint stars due N.
12	Innes 238 ...	8·2	5·3	44 38	·63	142·6	3·20	2·0	1	I.	A faint star 30″ N. The p.m. is inconsiderable.
39*a*	Innes 329 ...	6·6	5·9	60 58	·63	330·5	0·66	0·6	1	I.	
40*a*	Innes 330 ...	8 0	6·9	74 12	·63	2·1	1 63	1·0	1	I.	
41*a*	Innes 331 ...	8·0	8·7	68 13	·46	5·4	1·53	1·3	2	I.	
17	*h* 4742	6·9	8·8	75 12	·48	200·6	31·9	5·1	1	I.	
	„	„	„	„	·51	200·3	32·0	...	1	L.	
18	δ Circini	5·3	8 9	60 35	·63	315·6	10·4	5·2	1	I.	Identification a little doubtful, is otherwise Lac. 6259.
19	*h* 4750	7·3	9·3	47 40	·63	22·0	13·3	2·7	1	I.	A yellow, B reddish.
New	Innes 370 AB	5·4	10·8	60 8	·60	119·7	5 52	7·6	1	I.	Found with the 18-inch McClean telescope.
24	Harvard AC				·54	244·0	44·6	5·6	2	I.	

Ref. Cat.	Star.	Mag.	R.A. 1900 h m	S.D. 1900 ° ′	Epoch.	Angle. °	Dist. ″	Diff. of Mags.	No. of Nights.	Obs.	Remarks.
42*a*	Innes 332 ...	6·6	15 11·5	67 7	1900·60	107·9	0·92	2·0	1	I.	
New	Innes 371 (C.P.D. −58°, 5859)	8·9	14·5	58 30	·30	289·4	0·78	0·5	1	I.	Found with 18-inch McClean refractor. Is 11 sec. f. a little S. of Bris. 5272, mag. 8·0.
35	γ Circini ...	4·4	15·4	58 58	·36	79·1	1·12	0·5	1	I.	Smaller components certainly f.
	„	„	„	„	·41	82·0	...	...	1	L.	
39	Harvard (Lac. 6308)	6·5	16·8	67 57	·48	f.	50″±	4·5	1	I.	Harvard star 70°± 12″± 14^m not seen on two nights.
43	Innes 239 ...	7·0	22 6	31 8	·60	2·5	0·29	0·5	1	I.	
44	*h* 4771	8·0	22·6	57 46	·50	188·0	5·30	0·6	2	I.	Fixed.
48	*h* 4777	6·7	24·9	57 4	·50	298·2	5·88	2·0	1	I.	
50	*h* 4773	8·7	25·2	74 1	·42	242·1	6·54	0·2	2	I.	Colours slightly contrasted; pr. star yellowish, f. star bluish. Several small stars near, the closest 12^m·0 is N. pr., and there is a brighter star at double the distance.
55	γ Lupi	3·0	28·5	40 50	·54	90·0	0·34	0·2	3–2	I.	Smaller star follows. In contact. Nature of orbit still in doubt.
56	*d* Lupi	4·8	29·0	44 37	·46	358·8	2·42	...	2	I.	Prof. See's angle seems to require −10°.
60	Innes 242 ...	7·5	31·2	31 12	·61	47·4	1·72	0·1	1	L.	
62	ω Lupi	4·0	31·3	42 14	·56	25·8	11·6	7·2	2	I.	Chief star orange red. Common p.m. almost certain.
72	Bris. 5413 (Dunlop 190) AB	8·3	35·0	57 48	·47	93·2	5·68	2·0	1	I.	A red, B blue.
		„	„	„	·49	94·1	5·73	...	2	L.	
New	Bris. 5413 (Innes 372) AC	„	„	„	·48	50·0	33·8	3·2	1	I.	Found with the 18-in. McClean telescope.
		„	„	„	·49	48·7	33·9	...	2	L.	

Ref. Cat.	Star.		Mag.	R.A. 1900. h m	S.D. 1900. ° ′	Epoch.	Angle. °	Dist. ″	Diff. of Mags.	No. of Nights.	Obs.	Remarks.
74	*h* 4795 ...	...	7·4	15 36·9	58 48	1900·50	222·0	7·70	...	2	I.	Fixed. An $11^{m}\cdot0$ star $137^{\circ}\pm$, $20''\pm$.
80	Rumker 20	...	5·8	38·8	65 8	·50	153·1	2·15	0·3	2	I.	A 12^{m} star N. f. $40''\pm$. This would seem to be the nearer of the two stars noted at Arequipa.
82	Innes 245	...	7·5	40·0	43 56	·61	328·0	0·91	1·0	1	I.	
44*a*	„ 333	...	6·7	46·0	77 44	·48	133·7	0·84	0·1	1	I.	
93	Dunlop 195	AB	6·8	47·5	50 2	·37	10·8	12·0	0·5	1	I.	Colours slightly contrasted; A bluish, B yellowish. Fixed.
	„	„	„	„	„	·62	9·6	12·0	...	1	L.	
	„	AC	„	„	„	·37	289·3	28·9	...	1	I.	
	„	„	„	„	„	·62	289·9	...	...	1	L.	
101	*η* Lupi ...	...	3·8	53·5	38 7	·69	19·3	14·7	...	1	I.	The lesser star is orange red.
New	Innes 373 (Lac. 6655).		7·0	58·0	39 10	·69	217·8	8·74	4·0	1	I.	Found with the 18-inch McClean telescope. Also contained in a M.S. of new pairs received on October 20 from Professor E. C. Pickering. C.Z. xv. 3981, mag. 7·8 red, is 13′ N. f.
2	*h* 4831 ...	...	6·5	16 0·7	36 29	·68	358·5	40·7	5·5	1	I.	In Ref. Cat. substitute *h* 4831 for Harvard.
4	*β* 949 ...	...	6·5	3·0	9 50	·42	Not seen double			1	L.	
15	*δ* Triang. Austr. ...		4·0	6·3	63 26	·41	No comp. seen			1	I.	At Arequipa in 1891 Professor W. H. Pickering records a distant *comes*. The Cape observations refer to the close companion found by Mr. H. C. Russell at Sydney.
	„		...	...	...	·50	„			1	L.	
17	*θ* Normæ ...	...	5·3	8·0	47 7	·50	Nil.	...	...	1	L.	
						·68	Nil.	Moon	...	1	I.	
48*a*	Innes 335	...	8·5	8·8	71 12	·46	204·6	3·72	2·0	2	I.	Some faint stars 50″ away.

Ref. Cat.	Star.		Mag.	1900. R.A. h m	1900. S.D. ° ′	Epoch.	Angle. °	Dist. ″	Diff. of Mags.	No. of Nights.	Obs.	Remarks.
18	Harvard(Lac. 6735)		5·4	16 8·9	53 34	1900·68	...	...	...	1	I.	Two stars seen as in Ref. Cat. No star 290°. Many faint stars around, one $13^m.5$ at about 240°.
24	γ_2 Normæ ...		4·2	12·4	49 55	·68	0·9	41·9	5·5	2	I.	A deep yellow. Change probably due to the p.m. of A.
46	*h* 4854 ...		6·6	21·4	57 32	·41	Single	...	...	1	I.	Not a good night.
49*a*	Innes 336		7·4	22·9	62 4	·55	195·5	1·17	0·2	2	I.	
New	Innes 374 (Lac. 6874)	AB	8·0	28·4	51 2	·71	300·3	2·60	3·0	1	I.	Found with the 7-inch refractor.
		AC	„	„	„	·71	357·7	23·0	5·0	1	I.	Found with the 18-inch McClean telescope.
53	*β* Apodis ...		4·2	28·8	77 19	·46	72·3	51·3	...	2	I.	The known p.m. of *β* Apodis nearly accounts for the change shown since *h*.
61	Lac. 6912	AD	5·6	33·9	48 34	·69	162·0	13·1	4·4	1	I.	AB is Melbourne [8]. AC = *h* 4876. D, E, and F agree nearly enough with the Arequipa estimates. E was seen by *h* and is unchanged.
	„	AE	...	...	...	·60	14·8	13·5	5·4	2	I.	
	„	AF	...	...	...	·69	194·5	21·2	6·4	1	I.	
63	*h* 4874	AB	7·5	34·1	60 44	·37	296·9	3·40	0·0	1	I.	Colours slightly contrasted, f star yellowish. A 12^m star 10″ N. pr.
	„	„	...	...	...	·50	298·7	3·24	...	1	L.	
	„	BC	...	...	...	·50	325·2	14·9	...	1	L.	
65	Innes 39 ...		8·0	35·3	32 38	·69	...	...	...	1	I.	The only companion is a long way S.f.
67	Harvard (Lac. 6906)	AB	5·3	36·6	66 55	·41	104 ±	20 ±	6·7	1	I.	CB might be called a wide double near a bright star. Arequipa star 180° 30″ not seen.
		AC	„	„	„	·41	123 ±	25 ±	6·2	1	I.	
68	Harvard(Lac. 6927)		6·6	36·8	52 58	·51	N.f.	40 ±	5·4	1	I.	
69	„ (Lac. 6946)		6·4	37·0	37 58	·51	160 ±	50 ±	5·6	1	I.	
50*a*	*h* 4865 ...		8·9	41·1	83 50	·51	312·9	4·30	...	1	I.	

Ref. Cat.	Star.	Mag.	1900. R.A. h m	1900. S.D. ° ′	Epoch.	Angle. °	Dist. ″	Diff. of Mags.	No. of Nights.	Obs.	Remarks.
72	Innes 99	7·5	16 42·4	43 46	1900·69	75·2	1·12	0·3	1	I.	
New	Innes 375 (C.P.D. −40°, No. 7567)	9·8	46·8	40 54	·69	161·5	4·06	2·5	1	I.	Found with the 18-inch McClean refractor. Is 65 secs. pr. next star.
81	Innes 101 ...	9·0	47·9	40 54	·69	352·5	2·70	1·2	1	J.	
92	Harvard(Lac. 7052)	6·5	52·0	54 27	·68	71·2	20·2	6·0	1	I.	Difficult.
99	ϵ_2 Aræ	5·4	55·2	53 5	·68	Nil	Moon	...	1	I.	
103	*h* 4909	8·1	56·2	50 56	·37	158·8	11·3	...	1	I.	
106	*k* Scorpii	5·0	58·3	33 59	·51	Nil	...	...	1	I.	
108	Lac. 7123 AC	6·5	59·6	37 5	·68	187·2	43·5	6·5	1	I.	This is the Arequipa star. The close star = 10·5 mag. was seen here, but the first observation is due to Professor See. It is contained in a recent MS. list of stars since found at Arequipa.
5	Dunlop 214 ...	6·5	17 3·1	67 4	·39	350·7	28·7	...	2	I.	*Comes* double 95° ?
8	*h* 4920	6·9	4·3	58 28	·63	328·6	2·91	...	1	L.	
16	Lac. 7171 AB, C	7·0	7·5	39 39	·63	335·6	14·4	...	1	L.	*h* 4926. No mention made of the close pair λ 321.
	„ AB, D	...	...	...	·63	210·2	17 0	...	1	L.	
20	Innes 104 ...	6·5	9·1	69 56	·72	140·4	1·66	2·5	1	I.	
31	Brisbane ... (Lac. 7194) AB	5·5	11·4	46 32	·62	66·5	2·32	...	1	L.	Distance decreasing. Period probably under 60 years. p.m. = 0″·93 towards 77°·6.
	„ „	„	„	„	·63	69·6	2·13	...	8	I.	
	„ „	„	„	„	·71	69 7	2·36	...	1	G.J.	
	„ „ AC	„	„	„	·71	279·0	42·0	6·6	2	I.	
	„ „ AD	„	„	„	·71	30 ±	47 ±	8·4	1	I.	

Ref. Cat.	Star.		Mag.	1900. R.A. h m	1900. S.D. ° ′	Epoch.	Angle. °	Dist. ″	Diff. of Mags.	No. of Nights.	Obs.	Remarks.
33	*h* 4931 ...	...	7·5	17 11·8	59 20	1900·66	257·4	1·26	0·2	2	I.	Fixed.
35	Lac. 7215...	AB	5·9	12·1	34 53	·53	299·0	2·17	...	4	L.	(β 416.)
	„ ...	AC	„	„	„	·53	130·9	30·0	...	4–3	L.	*h* 4935.
39	Harvard (Lac. 7213)	...	6·4	14·3	57 55	·66	187·4	2·11	4·6	2	I.	Fine pair. A yellowish. Also 13^m star 270° distant; 11^m S. f. more distant, and other faint stars about. The 11^m was also noted at Arequipa.
42	ι Aræ ...	...	5·4	15·8	47 22	·67	62·0	43·0	5·3	1	I.	Noted in looking for the Arequipa star (335°, 15″ 9^m·0 W.H.P.)
New	Innes 385 (Bris. 6042)	...	7·5	16·0	59 7	·72	184·3	0·51	0·3	1	I.	Found with the 18-in. McClean refractor. Both yellow. A 13th mag. star 212°·6, 18″·6, and a 14th mag. star 113° ±, 35″ ±.
48	κ Aræ ...	AB	5·3	18·2	50 33	·67	159·4	76·4	4·4	1	I.	Arequipa stars not seen.
New	... ...	BC	„	„	„	·67	274·7	4·71	1·0	1	I.	
53	Harvard (Lac. 7265)	...	6·3	20·0	52 13	·67	...	...	...	1	I.	Many faint stars about; none within 30″–40″.
54	Harvard (Lac. 7263)	...	6·0	20·4	55 5	·67	151·1	37·2	5·5	1	I.	AC. B evidently not seen.
New	Cape 29 (C.P.D. – 42° 7799)	...	8·9	23·5	42 59	·67	339·7	4·90	0·8	1	I.	Found by Mr. W. H. Cox at the transit circle. Mag. from Cord. D. is 0·5 too faint. A similar but fainter pair N. pr.
New	Innes 376 (C.P.D.–65° 3457	...	9·0	23·9	65 57	·7	40 ±	1 ±	0·4	1	I.	Found with the 7-in. Closely S. pr. Bris. 6087, mag. 8·5.
64	Innes 40 ...	...	6·5	24·4	45 58	·63	210·6	17·8	4·0	2	I.	B bluish. The p.m. is very small.

Ref. Cat.	Star.	Mag.	1900. R.A. h m	1900. S.D. ° ′	Epoch.	Angle. °	Dist. ″	Diff. of Magr.	No. of Nights.	Obs.	Remarks
74	Innes 106 ...	7·7	17 29·6	49 11	1900·66	39·0	0·86	0·8	2	I.	
New	Innes 377 ... (U.A. 1 Pavonis)	7·0	34·7	57 40	·72	327·3	15·1	7·0	1	I.	A red 8 remarkable, is 8·8 in C.P.D. Found with McClean telescope.
89	Innes 248 ...	8·0	38·2	46 53	·69	127·8	1·78	1·3	2	I.	A 13^m star $13° \pm 30'' \pm$.
	ι_1 Scorpii ...	3·1	40·6	40 5	·63	96·3	37·0	8·7	2	I.	Weighted mean.
91	Innes 108 ...	9·3	41·0	40 6	·57	256·1	4·91	1·0	2	I.	
6	ι_2 Scorpii ...	4·9	43·2	40 4	·58	36·8	32·9	6·1	2	I.	
98	Harvard ... (P. 17h 236)	6·5	44·5	40 45	·69	194·2	27·8	5·5	2	I.	A orange yellow 4. Many faint stars at a little greater distance.
105	*h* 4992 ...	8·0	48·9	57 39	·69	13·9	4·28	0·6	2	I.	B yellowish. Change.
108	Innes 109 ...	9·3	49·4	28 4	·54	242·5	5·63	2·0	1	I.	
109	Cordoba (50) ...	7·3	49·9	39 55	·71	126·5	3·45	1·7	1	I.	A orange yellow, B intense blue; very remarkable.
116	Innes 230 ...	8·6	53·7	37 42	·62	140·3	7·88	1·5	2	I.	
125	Harvard ... (Lac. 7542)	6·4	58·1	35 54	·54	289·7	12·6	5·1	1	I.	
129	*h* 5014 ...	5·2	59·6	43 26	·63	240·7	1·62	...	1	L.	
2	Harvard ... (Lac. 7540)	6·5	18 1·1	59 3	·42	S.pr.	40″ ±	5·5	1	I.	And more distant stars. (For S. pr. to read N. pr. to agree with Arequipa?)
5	*h* 5021 (Lac. 7566)	7·7	3·6	56 26	·50	326·5	5·26	3·8	2–1	I.	No certain change. Wrongly identified by *h*, so that the note in Ref. Cat. requires alteration.
6	β 245 ...	5·6	3·7	30 45	·66	353·3	3·92	...	2	L.	Fixed.
7	*h* 5023 ...	8·0	3·8	40 27	·62	276·8	9·18	...	2–1	L.	
17	*h* 5032 ...	7·2	6·6	43 14	·54	Nil	...	...	2	I.	Neighbouring stars also examined.

Ref. Cat.	Star.	Mag.	1900. R.A. h m	1900. S.D. ° ′	Epoch.	Angle. °	Dist. ″	Diff. of Mags.	No. of Nights.	Obs.	Remarks.
19	Innes 111 ...	7·2	18 7·6	56 41	1900·60	305·4	0·84	2·5	2–1	I.	Observations discordant (310°·6, 300°·3).
28	Innes 249 ...	6·4	10·0	63 55	·60	4·3	7·10	4·6	2	I.	
54	Harvard (Lac. 7696) ...	5·8	21·3	57 35	·52	120·2	34·6	4·7	3–2	I.	A fainter and more distant comp. pr.
69	Innes 250 ...	7·5	34·1	42 16	·55	132·8	0·95	0·7	2	I.	
72	λ Coronæ Austr.	5·2	36·9	38 25	·55	215·0	29·3	3·8	2	I.	A fainter, more distant star 56° ±.
	AB	,,	,,	,,	·56	214·8	29·2	...	1	L.	
	,, AC	,,	,,	,,	·56	57·2	40·2	...	1	L.	
	Hargrave (C.Z. 18h 2002) ...	8·6	36·7	54 0	·60	131·3	3·74	0·1	2	I.	Measured by Hargrave as *h* 5057 in error. See next star.
74	*h* 5057	9·2	37·4	54 2	·60	79·9	12·1	1 0	2	I.	Three faint stars near, one of which is mentioned by *h*.
86	*h* 5066	6·7	44·0	41 11	·65	87·2	9·91	...	2	I.	No certain change. Colours slightly contrasted. A yellowish.
89	Innes 112 ...	6·7	46·6	47 24	·56	182·7	1·72	...	1	L.	The p.m. is very small.
	,, ...	,,	,,	,,	·58	181·4	1·54	2·8	2	I.	
96	Innes 113 ...	6·9	51·3	48 38	·55	230·4	3·07	4·1	2	I.	
100	Innes 252 ...	7·7	54·9	34 38	·61	5·9	0·97	0·3	2	I.	Prof. See misidentified this pair, and registered it as λ 367. Ref. Cat. 18h, No. 109, should be struck out.
101	Cordoba (53) ...	7·5	55·1	40 48	·60	Single	...	...	1	I.	The companion was observed on one night at Cordoba, on which occasion the chief star was not observed.

Ref. Cat.	Star.	Mag.	1900. R.A. h m	1900. S.D. ° ′	Epoch.	Angle. °	Dist. ″	Diff. of Mags.	No. of Nights.	Obs.	Remarks.
105	Harvard (Lac. 7949) ...	6·0	18 56·2	51 9	1900·48	77·3	21·7	5·7	2	I.	No other star seen.
107	ζ Sagittarii ...	2·7	56·3	30 1	·83	71·6	0·44	...	5	I.	Day observations. Weighted mean.
New	Cape 30 (C.P.D.–42°,8577) ...	8·7	56·3	42 47	·68	77·9	4·11	0·0	2	I.	Colours very slightly contrasted, pr. star yellowish. Found by Mr. J. A. J. Pead at the transit circle.
113	γ Coronæ Austr.	4·3	59·6	37 12	·62	142·7	1·94	0·0	2	I.	
	"	"	"	"	·65	142·4	1·81	...	2	L.	Professor's See's angle seems to require + 10°.
7	Harvard 152 ...	8·2	19 8·1	29 26	·82	260·8	1·07	1·0	1	I.	
8	Cordoba (55) ...	8·5	8·4	27 29	·70	329·1	2·21	...	1	L.	
9	Innes 114 ...	7·8	10·5	63 4	·64	285·0	0·53	0·5	2	I.	
13	β_1 Sagittarii ...	4·1	15·5	44 39	·65	77·9	27·9	...	2	I.	B deep yellow. Doubtful if all the change is due to the p.m. of the chief star.
14	*h* 5103	8·8	15·5	71 58	·51	244·2	13·3	2·7	1	I.	
	"	"	"	"	·61	243·7	12·6	...	1	L.	
16	Innes 115 ...	8·0	16·6	62 22	·56	54·7	2·83	2·9	2	I.	
	"	"	"	"	·61	56·0	2·97	...	1	L.	
17	Innes 116 ...	8·4	16·7	46 8	·55	30·2	2·31	1·0	2	I.	An orange-coloured star 17″ S. 8·6^m.
24	*h* 5114	5·4	19·8	54 31	·72	No comp. seen			1	I.	A golden yellow. C.Z. 19^h 774 which is pr.; has a 13^m *comes* 200° ± 10″ ±.
30	Innes 254 ...	8·0	23·1	48 38	·54	212·8	0·93	0·0	2	I.	
32	" 117 ...	6·9	23·4	60 29	·64	184·1	0·86	0·6	2	I.	
34	" 118 ...	7·0	25·5	46 59	·54	127·5	1·06	2·0	2	I.	A yellow, B bluish. Common p.m. of 0″·17 towards 159°·0.
35	" 255 ...	8·6	25·7	48 55	·54	173·2	2·49	2·6	2	I.	

Ref. Cat.	Star.		Mag.	R.A. 1900. h m	S.D. 1900. ° ′	Epoch.	Angle. °	Dist. ″	Diff. of Mags.	No. of Nights.	Obs.	Remarks.
47	Ḧ. I. 13	AB	7·1	19 33·2	10 23	1900·70	321·6	3·54	...	1	L.	
	„	AC	„	„	„	·70		Invisible			L.	Clear night, dark field.
	„	AD	„	„	„	·70	167·6	27·5	2·9	1	L.	
49	Innes 119	...	7·5	34·0	59 14	·61	180·6	1·27	...	1	L.	
	„		„	„	„	·65	179·3	1·18	0·9	2	I.	Both yellowish.
51	Cordoba (56)	...	7·0	34·5	53 11	·51	52·5	3·17	1·5	2	I.	
	„		„	„	„	·61	52·8	3·16	...	1	L.	
54	Lac. 8194	AB	7·0	40·2	62 3	·64	152·1	0·52	0·5	2	I.	Both yellowish. Innes 120.
	„	AB, C	„	„	„	·64	344·0	14·1	3·5	2	I.	No change in the wide pair. *h* 5141.
61	Innes 121	...	5·5	42·3	59 27	·64	89·0	0·63	2·5	2–1	I.	
62	„ 122	...	7·6	43·8	42 7	·61	340·3	5·17	...	1	L.	
			„	„	„	·62	338·4	5·04	2·5	2	I.	
64	Dunlop 227	...	5·3	44·7	55 13	·68	149·5	23·4	...	2	I.	A deep yellow. B blue, fine contrast. Fixed. A $12^m\cdot5$ star is 19″ ± N. pr.
66	*h* 5152 ...	...	8·1	47·2	30 31	·70	154·8	6·01	...	1	L.	
73	Innes 256	...	6·9	54·2	47 40	·70	201·4	0·99	2·0	2	I.	The p.m. is insensible.
7	*h* 5167 ...	...	7·3	20 2·9	63 55	·65	35·5	7·61	...	2–1	I.	No change.
8	Innes 123	...	7·1	3·5	47 2	·66	174·8	10·8	3·9	3	I.	A yellow, B blue. The p.m. is very small.
9	*h* 5173 ...	...	5·4	4·6	36 21	·66	122·0	9·09	...	2	L.	An important system of the 61 Cygni or P. XIV. 212 class.
12	*h* 5177 ...	...	8·1	6·9	57 16	·65	28·5	8·11	...	2	I.	No change.
13	*h* 5178 ...	...	6·9	7·3	34 25	·60	10·0	2·79	...	2	L.	

Ref. Cat.	Star.		Mag.	1900. R.A. h m	1900. S.D. ° ′	Epoch.	Angle. °	Dist. ″	Diff. of Mags.	No. of Nights.	Obs.	Remarks.
14	Innes 299	...	8·5	20 7·3	36 20	1900·75	39·0	0·54	0·3	2	I.	
17	„ 124	...	7·7	9·5	63 28	·71	Nil	...	...	3	I.	
18	„ 125	...	8·2	9·5	46 13	·70	42·2	1·46	0·7	2	I.	Slightly contrasted in colour, A yellowish. The p.m. is very small.
19	O. Stone (Lac. 8392)		7·3	10·6	32 55	·60	304·2	2·36	...	1	L.	
New	Innes 378 (C.Z. 20^h 287)		8·5	10·6	46 16	·70	148·7	3·94	3·5	2	I.	Found with the 18-in. McClean telescope.
28	Innes 126	...	9·0	15·3	57 26	·70	77·0	1·64	0·2	2	I.	
30	κ_1 Sagittarii	AB	5·7	15·6	42 22	·66	306·9	29·9	6·8	2	I.	The p.m. of the chief star almost accounts for the change since *h*. A more distant star S.
		AC	„	„	„	·66	277·0	50·7	5·8	2	I.	
48	Innes 127	...	9·0	27·1	44 51	·51	54·4	...	...	1	I.	1900·66. No sign of duplicity. I. 1900·82, single, medium definition, I. Still, there can be but little doubt that this is a double star, as it was picked up independently on *three* nights with the 7-in. There is a faint star between this and ν Microscopii.
53	α Indi	AB	3·2	30·5	47 38	·74	199·8	66·5	...	1	L.	
		AC	„	„	„	·74	344·5	63·0	10·8	1	L.	
61	Innes 129	...	8·0	36·3	52 9	·58	326·6	3·04	2·5	2	I.	
72	Rumker 26	...	5·8	43·3	62 48	·56	95·0	2·63	...	1	L.	
	„		„	„	„	·60	95·2	2·68	0·3	2	I.	

Ref. Cat.	Star.		Mag.	1900. R.A. h m	1900. S.D. ° ′	Epoch.	Angle. °	Dist. ″	Diff. of Mags.	No. of Nights.	Obs.	Remarks.
57*a*	Innes 337	...	8·9	20 45·4	87 27	1900·85	289·2	1·01	0·7	2	I.	In addition to the *comes* *h* 5192, there is an $11^{m}·0$ star 50″ S.f.
81	„ 18	...	7·4	47·9	52 30	·58	3·7	4·36	3·2	2	I.	
83	„ 129	...	7·7	48·6	59 39	·68	17·5	1·65	2·0	2	I.	A 13^{m} star 30° ± 30″ ±.
95	„ 130	...	7·0	57·3	48 21	·57	316·8	3·22	3·5	2	I.	
96	*h* 5233 ...	...	7·6	57·5	83 40	·60	269·3	11·7	3·9	2	I.	
New	Innes 379 (Lac. 8625)	AB	5·9	58·8	73 34	·82	138 ±	...	...	1	I.	Found and estimated with the 18-in. McClean telescope.
100	Harvard (Lac. 8625)	AB, C	„	„	„	·82	135·6	7·67	7·1	1	I.	AB is very close, the direction of B is towards C. AB = yellow 4.
1	Innes 301	...	9·0	21 0·6	36 55	·58	339·9	3·98	0·5	2	I.	
8	Innes 258	...	7·7	4·8	60 27	·72	102·7	0·59	0·4	2	I.	
15	*θ* Indi ...	...	4·6	12·7	53 52	·58	285·1	4·42	...	2	L.	
19	Innes 131	...	9·0	14·8	52 12	·73	Nil	...	...	1	I.	
20	Innes 132	...	7·5	16·1	52 22	·72	297·9	1·40	1 6	2	I.	
22	θ_2 Microscopii	...	5·9	18·0	41 26	·76	292·3	0·96	0·3	2	I.	Probably fixed, but the angles are very discordant, ranging over 41° !
27	*h* 5267 ...	...	7·2	20·0	46 30	·71	Nil	...	...	1	I.	A 13^{m} star 200° ± 25″ ±. The chief star has a p.m. of about 0″·13 towards 10°, but this hardly accounts for the disappearance of the *h* companion.
28	Melbourne (6)	...	5·6	20·6	42 59	·58	145·8	2·88	...	2	L.	
New	Innes 380 (Lal. 41984)		8·2	30·0	19 13	·84	356·0	1·34	0·8	1	I.	A white, B slightly yellowish. Found with the 7-in. With the 18-in. McClean telescope a $12^{m}·5$ star is seen at 71° ± 42″ ±.

Ref. Cat.	Star.		Mag.	R.A. 1900. h	m	S.D. 1900. °	′	Epoch.	Angle. °	Dist. ″	Diff. of Mags.	No. of Nights.	Obs.	Remarks
41	Innes 302	...	9·0	21	32·8	11	21	1900·84	89·4	2·48	1·2	1	I.	
45	λ Octantis	...	5·4		35·6	83	11	·49	77·7	3·35	2·5	1	I.	A yellow, B bluish.
	„	...	„		„	„		·58	80·5	3·10	...	2	L.	The change is very slow.
53	Innes 19 ...	...	7·0		40·9	65	58	·63	341·9	1·35	...	2	L.	
55	Brisbane (Lac. 8912)		5·7		41·8	47	45	·60	359·4	46·3	...	1	L.	
56	θ Piscis Australis		5·2		41·9	31	22	·86	339·0	35·9	5·3	2	I.	Common p.m. of 0″·65.
61	Cordoba (59)	...	9·2		43·5	54	52	·86	151·2	3·71	0·5	2	I.	Colours slightly contrasted.
58a	Innes 338	...	8·0		54·1	56	57	·83	279·3	0·88	1·4	2	I.	Angle = mean of 285°·2 and 273°·4.
New	Innes 381 (C.Z. 21ʰ 1813)		8·2		59·2	56	57	·86	112·5	1·85	1·8	2	I.	Colours slightly contrasted. A yellowish. Found with the 18-in. McClean telescope.
59a	Innes 339	...	8·5	22	5·8	75	29	·78	179·8	2·42	1·2	2–1	I.	
14	Innes 20 ...	...	6·8		11·0	63	19	·79	343·2	0·68	0·5	2	I.	
15	Harvard (Lac. 9076)		5·4		11·7	54	6	·86	16·3	2·30	5·1	2	I.	
16	Innes 303	AB	8·2		12·3	50	24	·75	33·0	25·4	...	2	I.	
	„	BC	„		„	„		·75	56·8	2·72	0·3	2	I.	
17	Innes 134	...	7·7		16·1	56	39	·82	307·5	0·58	0·3	2	I.	
18	π_1 Gruis ...	...	6·7		16·6	46	27	·75	201·6	3·05	5·0	2	I.	The p.m. is small and uncertain.
	„		„		„	„		·76	201·1	2·71	...	2–1	L.	(see above)
New	Innes 382 (π_2 Gruis)		5·8		17·0	46	26	·84	207·9	4·72	6·7	1	I.	Found with the 18-in. McClean refractor. The p.m. of the large star is 0″·22 towards 108°·7.

Ref. Cat.	Star.	Mag.	1900. R.A. h m	1900. S.D. ° ′	Epoch.	Angle. °	Dist. ″	Diff. of Mags.	No. of Nights.	Obs.	Remarks.
New	Innes 383 (Lac. 9112)	5·4	22 18·3	58 18	1900·84	247 ±	41 ±	9·1	1	L.	Found with the 18-in. McClean refractor, but too faint to measure. Retained on account of the p.m. of the chief star, which is 0″·384 towards 155°·8.
20	Innes 136 ...	7·5	19·9	45 37	·75	269·4	1·78	1·0	2	I.	Colours slightly contrasted, A yellowish, B bluish.
22	Innes 137 ...	6·9	20·8	58 31	·71	Not seen double			1	L.	
	,,	,,	,,	,,	·84	333·9	1·94	3·0	1	I.	
24	ζ Aquarii ...	3·8	23·7	0 32	·82	323·3	3·20	...	1	L.	
30	β Piscis Australis	4·5	25·8	32 51	·66	172·4	30·5	...	2	L.	
37	Innes 138 ...	6·6	32·0	40 23	·66	280·6	3·17	4·4	1	I.	
	,,	,,	,,	,,	·71	278·9	3·46	5·3	1	L.	
38	*h* 5348	8·5	32·7	59 20	·71	274·8	4·20	3·4	1	L.	The only complete measure.
39	Ħ IV. 117 ...	7·5	34·2	28 52	·85	60·1	3·16	...	1	L.	Fixed.
40	Lalande 180 ...	8·0	34·3	13 8	·85	314·5	4·01	...	1	L.	
48	Innes 304 ...	8·0	40·9	48 51	·61	358·3	4·49	0·2	1	I.	Colours slightly contrasted, A yellow.
	,,	,,	,,	,,	·78	359·9	4·46	...	2	L.	
49	Innes 140 ...	8·3	41·6	55 1	·61	271·3	4·24	1·5	1	I.	
	,,	,,	,,	,,	·85	269·1	4·46	...	1	L.	
New	Harvard (P. XXII. 224)	6·6	44·4	33 20	·87	90 ±	Doubtful		1	I.	Perhaps elongated, independent setting. Mr. Clymer at Arequipa gives 90° ± 0″·4 ± doubtful. Communicated by Professor E. C. Pickering.
New	Cape 31 (C.P.D. – 58°8008)	8·2	45·2	58 5	·87	172·9	7·85	0·5	1	I.	Found by Mr. Cox at the transit circle.

Ref. Cat.	Star.		Mag.	R.A. 1900. h m		S.D. 1900. ° ′		Epoch.	Angle. °	Dist. ″	Diff. of Mags.	No. of Nights.	Obs.	Remarks.
60*a*	Innes 340	...	6·0	22	45·7	63	43	1900·80	20·0	1·22	3·0	2	I.	A yellow, B bluish.
55	γ Piscis Australis		4·6		47·0	33	24	·77	267·9	4·08	...	1	L.	
57	Innes 22 ...	...	6·8		49·5	49	0	·80	184·7	0·45	0·2	2	I.	Both yellow.
67	Innes 259	...	7·5		58·3	55	34	·79	97·4	1·03	0·2	3	I.	
9	*h* 5387 ...	...	7·7	23	8·0	41	29	·85	277·4	7·84	...	1	L.	
13	Innes 143	...	7·2		9·6	60	14	·79	9·8	2·92	3·5	3	I.	A yellow 5, B bluish.
20	*h* 5392 ...	...	8·5		12·7	58	51	·72	331·3	20·9	...	1	I.	The change in this pair would be accounted for by a p.m. of 0″·23 towards 137° in the chief star. Its p.m. from meridian observations is doubtful in α and = −0″·20 in δ.
	„		„		„	„		·81	331·2	20·9	...	2	L.	
31	Innes 144	...	8·2		20·2	43	27	·74	180·3	0·80	0·4	2	L.	
37	Innes 23 ...	...	7·0		22·6	56	59	·74	321·8	0·84	0·9	2	I.	Both white.
38	Innes 145	...	8·7		25·3	58	40	·74	109·2	1·65	0·3	2	I.	
56	Cordoba (67)	AB	9·0		39·5	45	48	·87	307·3	4·03	...	1	L.	
	„	BC	„		„	„		·87	19·0	23·1	...	1	L.	
61*a*	Cape 25 ...	...	8·2		41·5	45	37	·64	167·4	2·49	0·2	2	I.	
60	Cordoba (68)	...	8·1		42·2	61	4	·67	101·0	5·94	1·0	1	I.	
	„	...	„		„	„		·78	100·8	5·60	...	2	L.	
61	Innes 305	...	6·9		42·8	51	27	·78	123·1	3·45	5·1	2	I.	A yellowish, B bluish.
	h 5428 (Bris. 7341)		6·7		48·4	66	30	·90	114·8	12·3	5·3	1	I.	No change since *h*. Common p.m. of 0″·12 towards 336°·5.
66	Innes 146	...	7·3	23	49·9	37	55	·84	221·9	0·74	0·7	1	I.	
	„	...	„		„	„		1900·85	217·2	0·82	...	1	L.	

Results for α Centauri.

Considerable attention was paid to *α Centauri*, because the star is passing through its greatest apparent distance. We have the following ephemerides :—

Date.	Roberts (A.N. 3313).		Doberck (A.N. 3330).		See (*Monthly Notices*, liv.)	
	°	"	°	"	°	"
1899·5	209·5	21·90	209·9	21·76	209·5	21·92
1900·5	209·9	21·94	210·4	21·79	210·0	21·96
1901·5	210·4	21·94	210·8	21·73	210·4	21·95

The screw value of the Repsold micrometer rests on seven sets of measures of the difference of declination between ζ_1 and ζ_2 *Reticuli*, made on 1899 December 2, 3, and 4.

The distance between these two stars was determined with the 7-inch heliometer, viz.—

	Distance.	Position Angle.
	"	° "
1900·0	309·99	35 44

Resulting value of 1 Rev. $= 17''\cdot685$.

On 1900 September 1 Mr. J. Lunt took some differences of declination of *Bradley* 2188 and *θ Ophiuchi*, which gave $17''\cdot664$; but as the difference of declination between these two stars has not been accurately determined this value has only been taken as showing that the adopted value is almost certainly correct within a $\frac{1}{500}$th part.

The periodic errors of the screw at their maximum amount to $0''\cdot03$. In repeated measures such as of *α Centauri* these are eliminated by altering the zero of the fixed wire, which has been done frequently.

The progressive errors are given in the following table :—

Rev.	Correction to be applied to the Reading.	Rev.	Correction to be applied to the Reading.
0	+0·0086	14	−0·0002
2	57	16	7
4	36	18	18
6	19	20	33
8	7	22	56
10	+0·0002	24	−0·0084
12	0·0000		

These rest on measures made by Mr. S. S. Hough and Mr. R. T. A. Innes on 1899 December 7, 8, 11, and 13.

Over the part of the screw used in the micrometer measures

these corrections are almost insensible. In the case of *α Centauri* the correction amounts to $-0''.005$, or so nearly equal to the correction for refraction that in this case the one has been taken as cancelling the other, viz.—

Hour Angle.	Correction for refraction to distance $21''.5$ of *α Centauri*.
h	"
−4	+0.006
−2	·005
−0	·006
+2	·007
+4	+0·007

The measures are :—

Date.	P.A.	Distance.	Observer.	No.	Telescope.
	°	"			
1900·07	210·5	21·71	L.	7 days	E.
·07	210·5	·77	I.	4–5 ,,	,,
·45	209·9	·96	,,	5 nights	W.
·50	210·4	·84	L.	7 ,,	,,
·64	210·7	·73	,,	3 ,,	,,
·66	210·2	·76	I.	7 days	,,
·82	210·3	·81	,,	2 ,,	E.

These measures are weighted according to the number of settings, the average number being five in angle and five double distances on each occasion.

It will be seen that the mean place, which is about $210°.4$, $21''.79$, agrees exactly with Dr. Doberck's ephemeris.

No temperature correction has been applied—the range was from 52° F. to 81° F.=29°, and the amount could hardly be so great as $0''.02$ on $22''$. It is hoped to obtain a good series of measures in 1901.

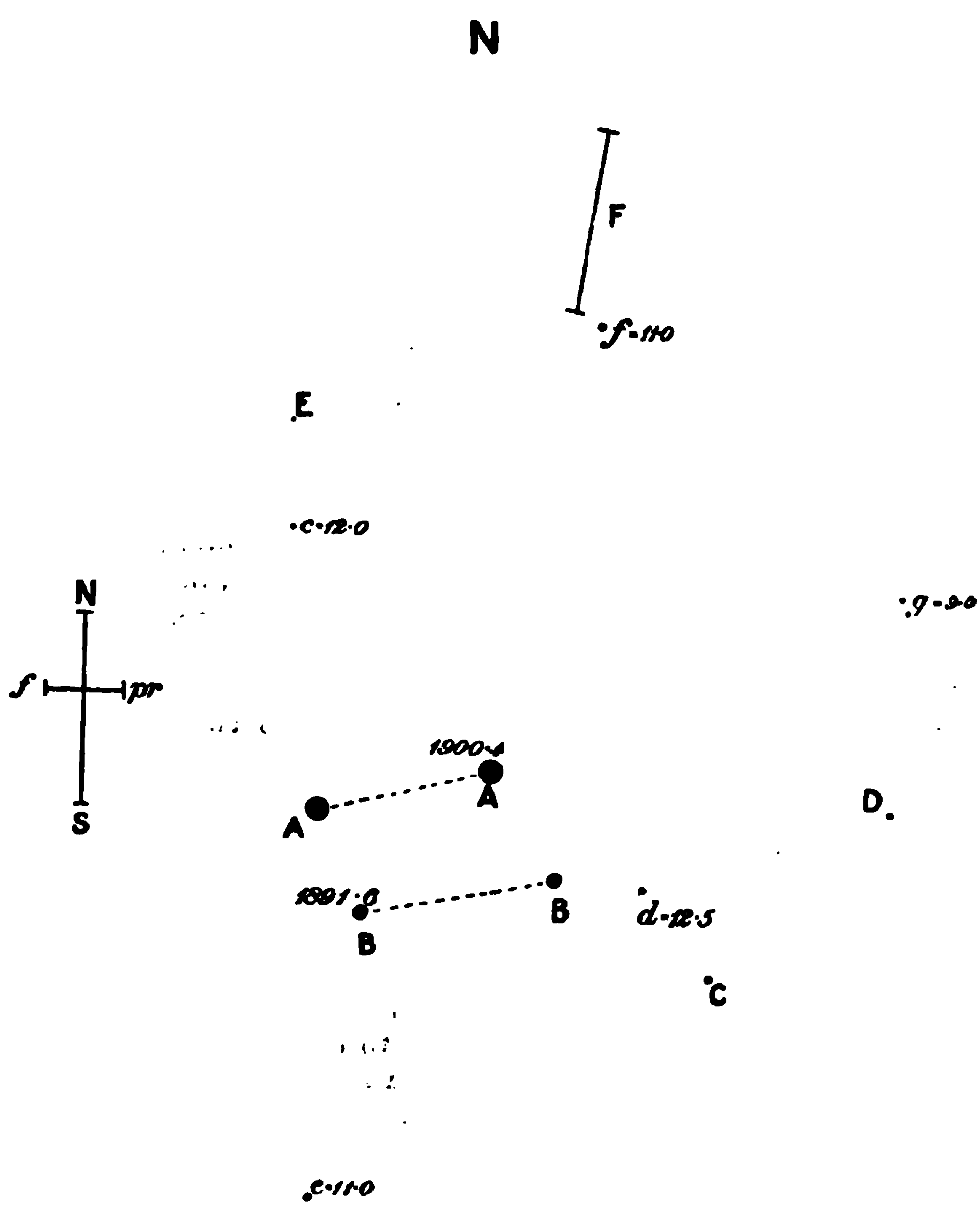
Besides the measures of the large star, some observations were also made of the faint stars in the same field.

Stars.	Date.	P.A.	Dist.	Observer.		
		°	"			
B−C	1900·48	236·9	32·7	I.	1n	Very poor measures, star C invisible when bright star in field.
A−D	·33	265·0	70·3	L.	1n	
,,	·37	264·3	69·4	I	1n	
A−E	·48	43·0	72·5	L.	4–3n	
A−F	1900·42	350·9	>73"	L.	1n	

In 1891 a careful examination of *α Centauri* was made at Arequipa (see *Harvard Annals*, vol. xxxii. pt. ii. p. 307), and the following positions obtained by estimation :—

Star.	Mag.	P.A.	Dist.
		°	″
c	12·0	5	50
d	12·5	257	60
e	11·0	180	70
f	11·0	330	100
g	9·0	290	110

To connect these with the Cape stars the following diagram has been made in which the change due to the great proper motion of *a Centauri* is shown :—



A study of the diagram shows the following identities :—

Arequipa.	Cape.
c	E
d	C
e	—
f	F
g	D

It is already evident that none of the stars E, C, F, and D belong to the system of *α Centauri*. D, which is evidently equal to the Arequipa *g*, has also been measured at Sydney, viz.—

1896·5	267°·2	82″·5	Sellors	3n

and the change between this and the Cape measures is due to the proper motion of *α Centauri* (3″·688 towards 281°·5). The star *e* was not observed here.

Royal Observatory, Cape of Good Hope:
1901 *January* 9.

New Form of Reflecting Telescope. By Charles Anthony, jun.

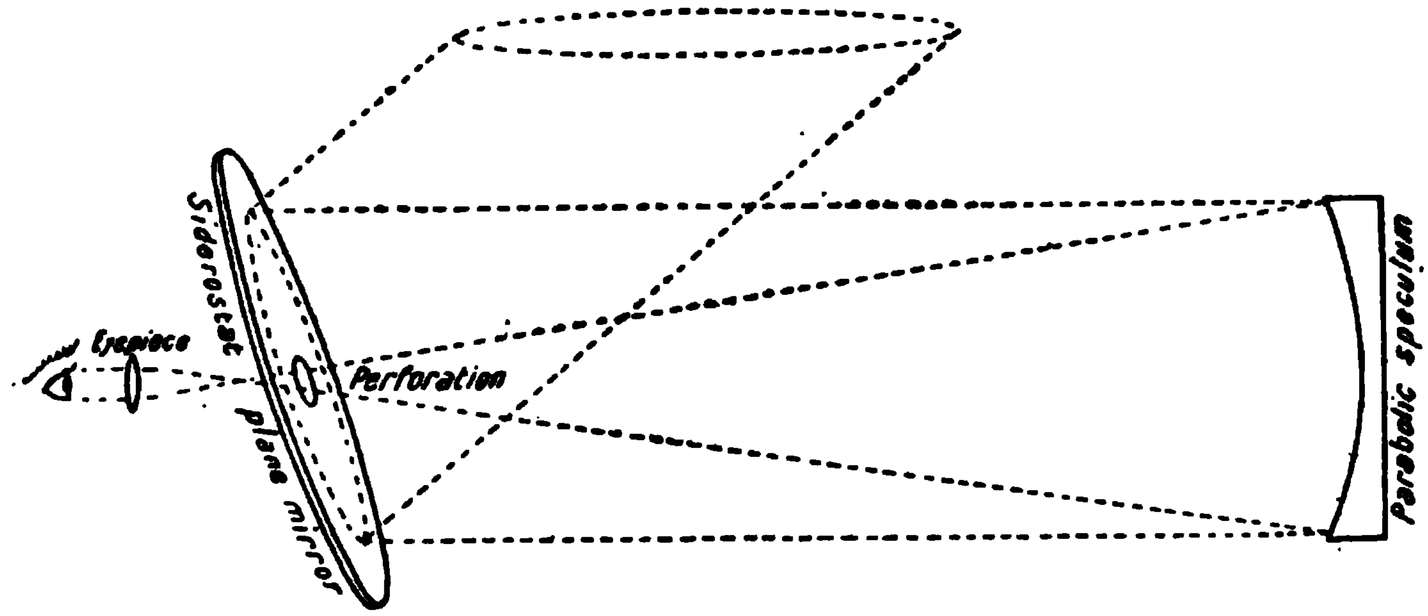
If the writer may be allowed to express his opinion on the best forms of mounting for refracting telescopes he would certainly say that for small and medium-sized ones he considers the movable elbow form to be the best, the observer's position being so eminently comfortable and convenient, and the loss by reflection being limited to one mirror in place of the two required in the original form of telescope coudé.

For large refractors the use of a siderostat, as applied in the large Gautier telescope at Paris, appears by far the best arrangement yet devised. The optical disadvantage is limited, as in the movable elbow form, to one reflection, a point more than compensated for by the observer's easy position.

The mechanical advantages are palpable, the unwieldy tube remaining fixed or being entirely dispensed with ; the portion to be driven by clockwork is thus limited to the plane mirror. The housing of such a telescope is likewise a much easier and cheaper matter than that of a great equatorial.

On the other hand, the improvement in the mounting of great reflectors appears to the writer to have lagged behind sadly in recent years. He therefore begs to bring forward an application of the siderostat, which appears to him to carry with it several concomitant advantages, making it a method even more

satisfactory for great reflectors than refractors. The idea illustrated schematically in the accompanying figure is briefly as follows :—



The speculum is mounted facing the siderostat plane mirror at a distance approximately equal to its focal length from the centre of the latter.

The plane mirror is perforated through its centre, thus allowing the image formed by the speculum to be examined and magnified by an ocular placed immediately behind the siderostat without further reflection by flat or small mirror, as in the Newtonian, Gregorian, or Cassegrainian form of instrument. This method of mounting in the case of reflectors, it will be seen, does not labour under the disadvantage of introducing additional reflections as in the refractor, reflection at the surface of the large plane siderostat mirror simply taking the place of that due to the usual flat or small mirror. It leads to the same comfort in observing, and is for the following reasons especially advantageous in the reflecting form of telescope.

The economy in mounting and housing is very great, as already pointed out in the case of refractors; and this would lead to the construction of reflectors of greater focal length in proportion to aperture, with the consequent improvement of their definition due to the elimination of the Schaeberlian aberration, which has, in consequence of the shortness of focus necessitated by exigencies of mounting, been only too much in evidence in most recently constructed large reflectors.

Further, the fixing of the speculum in a constant position overcomes the hitherto almost insurmountable difficulty of its flexure under its own weight when moved.

The plane mirror may be mounted as a cœlostat, but at the cost of some inconvenience. It will probably be found better to retain the siderostat method of mounting, modified by some such ingenious device for the mechanical compensation of the rotation of the field as suggested by Professor H. H. Turner in *Monthly Notices*, vol. lxi. p. 122, and H. C. Plummer on p. 402.

This method of mounting, admittedly good for great refrac-

tors, appears, therefore, to the writer even better adapted to reflectors, if modified as suggested by the piercing of the plane mirror, thus permitting of the elimination of the usual small flat or mirror; and he hopes to hear of its application in the near future in the construction of the next great reflector, which is to wrest the supremacy too long held in these latter days by the giant refractors.

In conclusion, he would point out that should it be objected that the close proximity of the observers to the plane mirror might impair the definition, this inconvenience can be overcome with little loss of light by the use of a long eyepiece constructed on the plan of a compound microscope, or by the use of a Barlow lens.

1901 *June* 19.

Note in Reply to Mr. H. C. Plummer's Paper (*Monthly Notices*, vol. lxi. pp. 368–375). By B. Cookson.

Mr. Plummer has pointed out that in the expression deduced on p. 136 for the weight of an observation-equation of a meteor the Q term should be non-existent. As this term is generally small compared with the P term, the weights will be but little altered by its omission, and consequently the values of the unknowns in the equations of condition, which were originally derived, will be only very slightly modified. In order to see how far this is true, some of the original sets of equations have been resolved with the corrected weights, and it is found that in no case is the probable error of beginning and end of path changed by more than $0^\circ{\cdot}02$—a quite insignificant quantity. In the most unfavourable case the coordinates of the radiant are changed by just one-half of their probable error, but in other cases by less than one-fifth of their probable error. The conclusions of the paper are therefore in no way affected. The correct expression for the weight is D^2/P, as indicated by Mr. Plummer, and the quantities printed in italics in the table in my paper are superfluous.

On the Accuracy of Photographic Measures: being a Discussion of a recent Paper by M. Loewy. By H. C. Plummer, M.A.

1. In the eighth Circular of the Conférence Astrophotographique Internationale, recently published, M. Loewy has recorded certain series of measurements on a photographic plate which have been designed and carried out in a definitely experimental spirit. On this material, which is beyond all

question of a most interesting and instructive kind, he has based an elaborate discussion. His conclusions therefrom lead him to formulate a very clearly defined programme of work in connexion with the *Eros* parallax plates. This programme of measurement is a particularly arduous one, and yet M. Loewy's position of deserved authority makes it appear likely that the attempt will be made at not a few observatories to carry out the scheme in its entirety. It is greatly to be feared that this course may entail a considerable delay in the publication of results. Any such effect would be most regrettable and is most strongly deprecated by M. Loewy himself in his introduction to the circular quoted. No excuse is needed therefore for an examination of M. Loewy's arguments and conclusions with a view of justifying if possible a considerable reduction of the proposed scheme of work. If it could be shown that M. Loewy has underestimated the accuracy of photographic measures, and that for an assigned degree of precision a smaller number of measures would suffice, the result would evidently be, to put the matter on the lowest ground, of considerable economic importance. Considerations of this kind have led me to examine M. Loewy's paper in some detail.

2. Of the three parts into which M. Loewy has divided his paper it is with the first only that I propose to deal. In the second he considers the accuracy of measurements which have been effected simply in the réseau lines imprinted on the plate, and in the third generalises his previous conclusions so as to obtain guidance and lay down definite rules for any circumstances that may arise. But at present it will be unnecessary to go beyond the first section.* The material for discussion has been obtained from a single plate bearing a triple image of each object. The number of stars employed is 82, the magnitude varying between 7·0 and 12·5. Each number recorded is a measure of a y-coordinate, and each has been obtained by setting the micrometer thread on the first réseau line, on each of the three images, and on the second réseau line, and then repeating the five settings in the reversed order. Thus each is the result of four settings on a réseau line and six bisections of a star image. Two tables have been formed, each containing eight measures in this sense of all the 82 stars. In Table I the measures were made by an observer A in successive orientations of the plate 0°, 90°, 180°, and 270°, and were similarly repeated by an observer B. In Table II, on the other hand, the measures were made by one of the observers alone and repeated eight times without altering the orientation of the plate.

* I may, however, take this opportunity to point out a slight slip which occurs on p. 24 of the paper. The mean value of $(2f^2-2f+1)$ when f varies from 0 to 1 is not $\frac{1}{2}$, as given, but $\frac{2}{3}$. The fraction $\frac{1}{2}$ is in fact the minimum instead of the mean value. Numerically the correction may be insignificant, but it is fatal to M. Loewy's contention that the combination of measures which is adopted in order to eliminate the effect of distortion of the film has the further advantage of minimising the consequences of accidental error.

3. By subtracting the mean from each group of eight determinations of y M. Loewy has formed the residuals and determined the probable errors. The values he gives are :

For Table I	0″·096
For Table II	0″·0385

The disparity is very striking, and its magnitude would hardly have been expected had not M. Loewy's work put the fact so clearly in evidence. That the repetition of measures under exactly similar circumstances would tend to reduce the discordances without increasing the accuracy in proportion is evident on general principles. That the effect of correlation is so noteworthy in this case is, I think, surprising.

4. M. Loewy at once bases on the constants given above a general numerical theory of the errors made in measuring a plate. He distinguishes between two kinds of error, the accidental and what he calls the systematic. The term "systematic" in this connexion is rather unfortunate and perhaps misleading. What is meant is that the irregular outline of an image will create a different impression on the mind of an observer when seen at different times and under different circumstances ; on the other hand, as M. Loewy very rightly says, "l'astronome, ayant défini *à priori* ce qui lui paraît être les centres des deux images à comparer, s'efforcera toujours de les pointer aussi bien que possible en restant fidèle à son interprétation primitive, et commettra une erreur constante qui ne sera pas éliminée par la répétition des pointés." Thus we may admit the existence of a source of error which may be to some extent mitigated by repetition of observations under carefully varied circumstances. This is not altogether what is generally understood by systematic error, by which is more usually meant that class of error which is not subject to the axioms of the Theory of Errors, and cannot, therefore, be eliminated by mere repetition of observations. No one could think of accusing M. Loewy of heresy in an elementary matter of this kind, and yet it is rather difficult to follow him when he says (of the systematic error in his own sense) : "Cette dernière quantité peut encore renfermer, par exemple, les petites variations que peut subir la couche de gélatine elle-même sous l'action des divers agents chimiques." Anomalous effects arising in the process of developing the plate are clearly systematic in the ordinary and not in M. Loewy's sense. Perhaps the sentence quoted is not intended to bear the meaning I have given it, but it is certainly equivocal.

5. We may follow M. Loewy in denoting the accidental and systematic errors by E_a and E_s respectively, and the total probable error by E_t, and admit that $E_t^2 = E_a^2 + E_s^2$. The number of settings on each image in a given position of the

plate is denoted by n and the number of orientations by n'. Then M. Loewy writes down the general formula

$$E_t^2 = E_a^2/n + E_s^2/n'$$

without further explanation. Surely the appropriateness of this formula is not obvious. If for one orientation we have $E_t^2 = E_a^2/n + E_s^2$ it might be expected that when the operation is performed in n' orientations we should have $E_t^2 = E_a^2/nn' + E_s^2/n'$. But in any case the point happens to be unimportant. It will be convenient to denote M. Loewy's formula for E_t by $E(n, n')$. Now the results derived from the two tables of measures give at once

$$E(2, 1) = 0''{\cdot}096 \text{ and } E_a = 0''{\cdot}0385 \times \sqrt{2}$$

It follows at once that $E_s = 0''{\cdot}088$. M. Loewy has then constructed on this basis a table of probable errors for all values of n and of n' from 1 to 10. From this it is an easy matter to select the most economical way of arriving at any required degree of precision. M. Loewy decides in favour of two settings in each of four orientations of the plate and expects a probable error $E(2, 4) = 0''{\cdot}058$. The labour involved in carrying out this programme will be four times that expended in measuring catalogue plates for the Carte Photographique, and yet if M. Loewy is right the accuracy will not be doubled.

6. Now there are two objections to the validity of M. Loewy's conclusions which suggest themselves quite naturally. They do not as a matter of fact prove substantial, and yet M. Loewy might have disposed of them by anticipation. He has made no reference to the systematic error of personality; and while he has contrasted results obtained jointly by two observers with results obtained by one alone, he has given no justification for supposing that the two are equally skilful and therefore directly comparable. I have been led in consequence to examine these points, but with a negative result. Addition of the residuals according to each observer for each orientation only served to indicate the following constant errors:

	0°	90°	180°	270°
Obs. A	+0′·0001	+·0008	−·0003	−·0005
B	+ ·0009	−·0001	−·0017	+·0008

These are too small to be of serious account, but they have been removed, as is clearly allowable, before the following errors of mean square were determined:

	0°	90°	180°	270°
Obs. A	0′·0024	·0020	·0024	·0016
B	·0024	·0027	·0022	·0026 .

These are as well accordant as could have been expected; they lead to a mean probable error $0''{\cdot}094$, which is quite close to

M. Loewy's value. The divergence between the mean probable errors for A and B ($0''\cdot08$ and $0''\cdot10$ respectively) is, however, sufficient to warn us against laying too much stress either on small differences or accidental coincidences between numerical estimates of probable error.

7. There is, however, a striking anomaly which manifests itself in the residuals of B in orientation 90° and 270°, and which deserves mention. If they are summed for the first 52 and last 30 stars separately this is the result :—

	90°	270°
	′	′
First 52 stars	$-0\cdot0558$	$+0\cdot0906$
Last 30 stars	$+0\cdot0491$	$-0\cdot0294$

Or in the mean

″	″
$-0\cdot07$	$+0\cdot11$
$+0\cdot10$	$-0\cdot05$

This suggests that B's measures in 90° and 270° may have by some means become interchanged in the latter half of the list. It is, of course, impossible to decide at what point this may have taken place. But interchanging the later sums as given we obtain for B's personal equation in these orientations the numbers

$$-0''\cdot06 \qquad +0''\cdot10$$

And if we now make allowance for these constant errors we shall reduce the errors of mean square to

$$0'\cdot0024 \qquad 0'\cdot0022$$

and so improve the agreement with A. But the total probable error will not be materially altered. The explanation I have suggested may perhaps appear rather fanciful. Yet it seems the only alternative to a conclusion so grave that we should naturally hesitate to accept it. This is that a skilled observer in the course of a series of measures is capable, owing to a sudden breach of continuity in his personality, of introducing and maintaining a constant discordance amounting in this instance to nearly $0''\cdot2$.

8. My next step was to compare directly the two means of the measures recorded in Tables I and II of M. Loewy's paper. The result of the comparison is set out in column I of the table given on p. 624. The differences are given in the sense Table II–Table I. There is an indication of a constant error in Table II of about $+0'\cdot0009$, or the same as that of B in orientation 0°. The identity of the observer is not revealed, and it would be interesting, though not very important, to know whether the coincidence is accidental or not. In order to appreciate the

significance of the table of differences it is necessary to realise that each mean is based on no less than forty-eight bisections of star images. I am not sure whether a second observer is to be reckoned as doubling the number of orientations or merely the number of settings. But whether the probable error to be assigned to means from Table I is E(4, 4) or E(2, 8) does not happen to matter. In either case M. Loewy's theory furnishes a probable error of 0″·102 for the differences between the two means, while a direct determination from the squares of the discordances gives 0″·114. That is to say, M. Loewy's numbers actually underrate if anything the untrustworthy nature of measures effected in a single orientation of the plate.

9. M. Loewy has then exposed a serious source of fallibility in measures of a photographic plate, and we come now more particularly to the consideration of the remedy he has proposed. This consists in altering the position of the plate between successive series of measures. A good idea of the effect of this procedure will be gained by a comparison of the mean of the measures of A and B in orientations 0° and 90° with those effected in orientations 180° and 270°. The discordances are given in column II of the table below. Counting the number of observers as virtually multiplying the number of orientations we derive from M. Loewy's formula the probable error 0″·082 for a difference. On the other hypothesis it is 0″·096 and as actually determined it is 0″·093. We notice at once that column II has a more satisfactory aspect than column I, especially when we consider that the means employed are based on twenty-four bisections, while column I rests on twice that amount of material. So that up to a certain point M. Loewy's theory stands confirmed, and we must admit that a source of error exists which can be mitigated only by increasing the number of orientations. It certainly seemed to me at this stage of my examination that M. Loewy's views were substantially correct, and yet one might hesitate before accepting his practical conclusion that it is necessary to make measures in four orientations. Exact experiments are even yet wanting which would enable us to draw a line of certainty between the exaggerated fears of some and the excessive confidence of others in regard to the accuracy of the photographic method. But systematic error must of necessity and undoubtedly does exist, though we cannot exactly gauge its magnitude. It might then be justly argued that just as M. Loewy has proved that it is unprofitable beyond a certain point to multiply the number of settings in one orientation on account of the tendency of an observer to repeat his own errors, so a limit may be quickly reached to the number of orientations of value proportionate to the labour expended on account of the existence of the systematic error. And, further, just as the remedy for the one danger is to increase the number of orientations, so the remedy for the second difficulty is to employ a large number of plates. The argument may be

Y Y

rendered numerically definite by a reference to M. Loewy's own table of probable errors. There we find $E(2, 4)=0''\cdot058$ and $E(2, 2)=0''\cdot073$. These are in the ratio of 4 : 5. But when the systematic error is taken into account, even though it be comparatively small, the ratio of the complete probable errors will be much nearer unity. It becomes then a serious question whether it is worth while to double the work of measurement for the sake of so small an advantage. There is one other point which may be alluded to here. The uncertainty which we now see attaches to the mere measurement of a photographic plate will doubtless be regarded by those who are doubtful of the accuracy of the photographic method as strong confirmation of the justness of their scepticism. It may be so. But the advocates of the comparative advantages of direct micrometrical methods may perhaps notice that the argument is rather a double-edged weapon. The magnitude of the uncertainty has manifested itself because it is easy to vary the conditions of observing. But we are just as sharply reminded on the other hand that the mere agreement of observations is a very deceptive guide as to their excellence. It may be something of a scientific platitude to remark that small probable errors may indicate repetition and not avoidance of error, but it is seldom so emphatically enforced as by the material which M. Loewy has put on record.

Table of the Number of Errors between given limits.

Limits.		I	II Numbers.	III
Extreme errors	... ...	$-0''\cdot37$	$-0''\cdot46$	None
$-0''\cdot24$	$-0''\cdot18$	4	2	3
$-0\cdot18$	$-0\cdot12$	9	3	8
$-0\cdot12$	$-0\cdot06$	7	7	17
$-0\cdot06$	$0\cdot00$	14	14	21
$0\cdot00$	$+0\cdot06$	10	16	19
$+0\cdot06$	$+0\cdot12$	10	15	10
$+0\cdot12$	$+0\cdot18$	8	13	4
$+0\cdot18$	$+0\cdot24$	6	4	0
$+0\cdot24$	$+0\cdot30$	6	2	0
$+0\cdot30$	$+0\cdot36$	4	3	0
Extreme errors	... ...	$+0''\cdot41$	$+0''\cdot37$	None
		$+0\cdot46$	$+0\cdot41$	
		$+0\cdot52$		
Probable errors		$\pm0''\cdot114$	$\pm0''\cdot093$	$\pm0''\cdot057$

10. I come now to a new fact disclosed by the examination of M. Loewy's data, and one which I regard as of great interest

and no little importance. It throws a new light on the whole question and it demonstrates the insufficiency of M. Loewy's formula as a complete representation of the facts. The means were formed of A and B's measures in orientations 0° and 180°, and again in orientations 90° and 270°. The discordances are analysed in column III of the table given above. For the purpose of applying the formula of M. Loewy they are based on just the same material as those appearing in column II, and the resulting probable errors ought to be equal or nearly so. On the contrary they are, as a matter of fact, *absolutely different*! The vast improvement effected by the new grouping of measures is shown much more clearly by the analysis of the discordances than by the mere probable errors, though these latter are of themselves significant enough. Thus our new probable error is exactly half of that given in column I and less than two-thirds of that given in column II. It seems quite possible that M. Loewy's formula may in general apply to results which have been obtained by merely multiplying the orientations at random. But we must now conclude that *by combining measures in orientations 180° apart* (i.e. *with the plate reversed*) *we shall effect a much greater improvement of accuracy than by a random choice of orientations.* Before considering the inferences which can be drawn from this principle I set down here some comparison numbers for the three cases :—

	I	II	III
The numerically largest error ...	$0''.52$	$0''.46$	$0''.23$
No. of errors $> 0''.3$	8	6	0
„ „ > 0.2	21	11	3
„ „ < 0.1	35	47	61

This is merely of course a brief epitome of the previous table, but I hope it will assist to place in the strongest possible light the salient features of contrast.

11. Now numbers like these prove with ample clearness that our last mode of grouping the measures must have eliminated some source of error which cannot be removed by combining observations in two orientations at right angles. Hence we can infer something as to the nature of the "systematic error" of M. Loewy, or at least of a considerable part thereof. It must to a great extent *remain constant for each image when the plate is reversed*, for it is eliminated in great part by taking the mean. On the other hand it *cannot be constant either in magnitude or sign from star to star*, since it escaped the search for a truly systematic error. An error possessing these qualities must always be somewhat difficult to detect. Yet serious consequences may follow if we ignore its existence, for in general it will not obey the axioms on which the ordinary theory of errors is founded. In such a case, as indeed in the one under consideration, special precautions are required if we are to avoid its

disturbing effects. I do not mean to say that the whole error, apart from what is purely accidental, can be removed by simply reversing the plate. But so great an improvement can be effected in this way that this method of procedure must be considered a matter of necessity when measures of the highest precision are required. And already the principle has been adopted in practice, although its function has not, I believe, been thoroughly understood. The causes and amounts of the variations of the error in question cannot at present be precisely determined, though they seem clearly to depend in a general way on the character of the photographic image. Some further remarks on this point will be found in § 14 of this note. One suggestion of a practical kind may be put forward here. We may reasonably conjecture that the magnitude of the deviation will be affected by the psychological condition of the observer at the moment. This factor is obviously liable to change; we have already noticed an extremely serious example of the phenomenon in § 7 unless it can be explained away as I have suggested. At any rate it will be of great advantage to curtail as much as possible the interval elapsing between the measures effected in the direct and reverse position of the plate. This consideration will lead us to suppose that a reversing eyepiece may prove an important adjunct to the measuring machine. It is interesting to notice that this feature has been adopted by Mr. Hinks in designing the new Cambridge machine, and that in his description of the instrument (*Monthly Notices*, lxi. p. 448) he says: "A reversing prism in the microscope, by means of which the field of view can be rotated, is very useful in avoiding personality in measurement." Possibly it would not be speaking too strongly to say that some device for achieving the object in view is not merely useful, but indispensable if the highest accuracy is to be obtained.

12. We have now established, as I think, a firm principle on which to proceed. The line of further search is now clear. Evidently we must regard as the unit of measurement, *not* a measure made in a single orientation, *but* the mean of two effected on the plate in the direct and reversed position. If measures are to be multiplied beyond this extent it is not to be supposed that nothing will be gained by changing the orientation. But that question now appears to be rather of subsidiary importance. I have formed the mean residuals according to the basis suggested, and find for the probable values of the divergences from the complete mean:

	0° and 180°	90° and 270°
A	0″·056	0″·049
B	0·061	0·055

from which I deduce the absolute probable errors

A	0″·065	0″·053
B	0·073	0·062

giving 0″·063 for the mean. The errors of B, considered in this aspect, are rather worse than A's; but not to insist too strongly on small differences of numbers in a matter of this kind we may estimate the probable error of an observer who makes double measures in both the direct and reversed position of a plate at about 0″·06. I believe that the accuracy of measurement at which M. Loewy aims can be substantially obtained with the expenditure of half the labour that he proposes to devote to this object; and if his programme is carried out the probable error arising from the process of measurement alone may be reduced to 0″·04, while the result of this increase of accuracy in this one department of the work will not be commensurate by any means with the labour expended.

13. Certain subsidiary comparisons seem to show that the estimates formed of the probable errors of the principal means for A and B are too large rather than too small when combined according to the theory of errors. Let these means be denoted by α_1, α_2, β_1, and β_2. Now we have already found (in column III of the above table) that the probable error of $\frac{1}{2}(\alpha_1+\beta_1-\alpha_2-\beta_2)$ is 0″·057, whereas the numbers of the last paragraph give 0″·063. So, again, in order to determine whether there would be any advantage to be obtained by combining the means for A in one orientation with those for B in the other the probable error of $\frac{1}{2}(\alpha_1+\beta_2-\alpha_2-\beta_1)$ was determined and found to be 0″·062. The probable value of $(\alpha_1-\alpha_2)$ appears to be 0″·077, while calculation from our constants would give 0″·084. Finally the probable value of $(\beta_1-\beta_2)$ is 0″·096, and agrees perfectly with the calculated value. In these last differences, it may be mentioned, thirty are positive and fifty-two negative; a fact suggestive of abnormality. As we are here dealing with the principal means we are, of course, independent of the truth or otherwise of the suggestion made in § 7. On the whole, then, we have some evidence that the residual "systematic" error (in M. Loewy's sense) is certainly small after the treatment of the measures which we have been led to adopt.

14. Owing to the peculiar nature of the error mainly under discussion it would be interesting to inquire into its relation to star magnitude. The material contained in M. Loewy's paper is not ample enough to decide this question. But I have rearranged the residuals according to magnitude and derived the following results from the means. The stars here have been placed in three groups, and the number and magnitude given for each.

		31 stars. > 12	41 stars. < 12, > 10	10 stars. < 10, > 7
	°	″	″	″
A	0	−0·05	+0·02	+0·10
	180	+0·03	−0·01	−0·19
	90	+0·01	+0·04	+0·17
	270	−0·02	−0·02	−0·08

		31 stars. >12	41 stars. $<12, >10$	10 stars. $<10, >7$
	°	″	″	″
B	0	+0·04	+0·05	+0·16
	180	−0·05	−0·11	−0·17
	90	−0·07	+0·03	+0·01
	270	+0·11	+0·01	0·00

The material is scanty, and more reliable evidence is to be desired; and yet a glance will reveal a very distinct tendency towards a progressive change of about 0″·04 per magnitude. The quantity is small certainly, and doubtless negligible in Astrographic Chart work; but in our discussion it is of the same order as the small quantities with which we have been dealing in forming the probable errors. The matter seems quite worthy of further study. At the same time when ampler data are available it would be interesting also to examine the relation of precision to star magnitude. Under the present circumstances it has seemed to me unprofitable to attempt a solution of this question.

15. *Summary of conclusions:*

(1) M. Loewy's contention with regard to the fallibility of measures made in a single orientation of the plate is substantially correct. The facts can *not* be explained by a constant personality or by the inferiority of one of the observers.

(2) A certain improvement in the accuracy of the result can be reached by measuring in different orientations (such as 0° and 90°).

(3) If M. Loewy's estimate of the precision of measures so made be accepted, it does not follow that it is worth while to repeat the measures as many times as he thinks necessary.

(4) By combining measures made in the direct and reversed position of the plate a much better result is obtained to which M. Loewy's formula does *not* apply.

(5) Sufficient accuracy will be obtained by making double measures in these two positions of the plate, and *the labour demanded by M. Loewy may be reduced by one-half.*

(6) The error eliminated by reversing the plate is definite for each image, but may vary both in magnitude and in sign from one star to another.

(7) Some means of reversing quickly is desirable, in case this definite error is liable to change with lapse of time.

(8) The probable error of the mean of double measures made in orientations differing by 180° is about 0″·06. The residual error (other than the accidental) is small, and up to a certain point measures in this sense will obey the ordinary laws of accidental error.

(9) There is some evidence that personality varies considerably according to star magnitude.

University Observatory, Oxford:
1901 *September* 5.

The Green Flash at Sunset.
By Professor William H. Pickering.

(*Communicated by the Secretaries.*)

As an independent confirmation of the observations described in Mr. Franklin-Adams's paper published in the *Monthly Notices* for May 1901 I would say that in the early part of last June I was watching the Sun set from the deck of a steamer not far from the coast of Cuba. At the instant that the Sun disappeared its last ray suddenly turned from red to a distinct blue. The effect was very striking, and I turned to the first officer of the steamer, who was standing beside me, and asked him if he noticed it. He replied that he did, and that he had never observed it before. The sea was very smooth at the time, and I did not notice the appearance resembling Baily's beads.

Mandeville, Jamaica, W.I.
1901 *July* 3.

Note on Two Stars in the Revised Madras Star Catalogue for 1835.
By A. M. W. Downing, D.Sc., F.R.S.

Dr. Herman S. Davis, who is engaged on the re-reduction of Piazzi's observations, has called my attention to certain errors in Piazzi's Catalogue affecting two stars in the Madras Catalogue. I am much obliged to Dr. Davis for his kindness in communicating these particulars to me.

No. 5835. This is really Piazzi xii. 169. Piazzi has the wrong sign for the declination in his catalogue.

No. 8791. Piazzi's declination is in error by $3' 40''$ on account of his adopting as the place of one star the mean of the observations of the two stars A. G. C. Leipzig II. Nos. 9075 and 9081, with the R.A. of the former of which Piazzi's R.A. agrees.

Taylor obtained one observation of the declination of Leipzig II. No. 9075, at the date 1836·56, with concluded result $+7° 51' 31''\cdot49$. The corresponding R.A. is $19^h 3^m 0^s\cdot23$, with precession in R.A. $+2^s\cdot894$.

These results should be substituted for those in the revised catalogue.

Taylor was misled by Piazzi's erroneous declination, and apparently observed in declination a faint star not far from the erroneous place.

Observations of Comet 1901 I. *observed at Perth Observatory, Western Australia.*

(*Communicated by W. Ernest Cooke, Government Astronomer.*)

The first record of the appearance of the comet seems to come from the natives in the Balladonia District (south coast), who saw it on the early morning of April 22. They reported it to the telegraph master at Balladonia on that day, and again on the 23rd, and he saw it on the 24th, but did not wire particulars. On the morning of the 24th, however, Mr. Tattersall, head keeper of Cape Leeuwin Lighthouse, noticed and reported a bright comet in the east about 6 A.M. I was in Adelaide at the time, and visited the observatory next morning (25th) and succeeded, in conjunction with Sir Charles Todd, in obtaining glimpses between the clouds and measuring a rough position by means of the equatorial circles. This, I believe, was the first observation made anywhere. It was then so bright that its tail, a triple one, could be seen almost up to sunrise, and its nucleus was visible in the 8-inch telescope for some time after the Sun was above the horizon. Unfortunately it was densely overcast during the remainder of the day, otherwise I think I might have been able to determine its position with the transit circle. It was then rapidly approaching the Sun. In Perth the mornings were densely cloudy until Saturday, April 27, when the first approximate position was obtained ($1^h\ 53^m\ 50^s$ R.A. and 88° 42′ N.P.D.) by means of the circles, but the sky was altogether too bright to obtain a photograph. The only note made as to its physical appearance was, "Comet bright, with two distinct tails." The next two mornings (28th and 29th) were brilliantly clear, but no sign of the comet was visible, although the observer examined the eastern horizon carefully with a good pair of field glasses. On the evening of May 1 it was observed low down near the western horizon, and two photographs (1^m and 10^m exposure) were obtained with the astrographic telescope. From this date until it was lost in the moonlight a long and a short exposure photograph were taken every evening when the state of the weather permitted. On some occasions the comet was just glimpsed for a few seconds, and only circle readings were taken. All the observations were made and plates measured by Mr. Johns, who has had several years' experience at astrographic work at both Greenwich and the Cape, and I think the measures can be taken as accurate, on the whole, to within $0''\cdot5$. With regard to the reductions I am not quite so certain. I have not had the time to obtain plate constants, and in some of the earlier plates it would not be possible, owing to the lack of stars. I have every reason, however, to believe that the orientation of the réseau was very correct. As to the scale value of the réseau, I have applied a correction of $-\frac{1}{250}$ to every difference. This was

obtained from an independent investigation, and appears to be corroborated, *on the average*, by the present stars. I have, of course, reduced my réseau coordinates to R.A. by the usual formula, and corrected for curvature, but *not* for differential refraction and aberration.

The discordances amongst the individual results appear to me to be large, but they do not seem to indicate any systematic error of reduction. They may be, and probably are, due to wrong positions for the stars at 1901·0, either through inaccuracies in the original observations, or else proper motion. I think, however, that the mean of the positions obtained for each day will be a good determination of the comet's place.

Position of Comet a 1901 *from Photographs.*

Date G.M.T.	Name of Object.	Rect. Coords. R.A.	Rect. Coords. Dec.	Mean Pos. of stars 1901·0. R.A.	Mean Pos. of stars 1901·0. N.P.D.	dα.	dδ.	Mean Pos. ☄ 1901·0. R.A.	Mean Pos. ☄ 1901·0. N.P.D.
d h m s				h m s	° ′ ″	m s	′ ″	h m s	° ′ ″
May 1 22 34 32	☄	42·967	13·800						
	4165 P.	30·531	15·361	3 26 0·94	90 49 7·8	−4 8·74	− 7 46·4	3 21 52·20	90 41 21·4
3 22 23 37	☄	43·174	13·854						
	4537 P.	53·528	26·729	3 47 7·13	91 26 43·2	+3 26·33	−64 7·1	3 50 33·46	90 22 36·1
	4540 P.	53·157	20·788	3 47 14·10	90 57 8·7	+3 18·90	−34 31·9	33·00	36·8
4 22 29 41	☄	42·751	11·970						
	4803 P.	43·150	4·405	4 3 36·38	89 28 39·8	+ 7·95	+37 40·4	4 3 44·33	90 6 20·2
	4810 P.	41·775	11·690	4 4 4·24	90 5 0·1	− 19·44	+ 1 23·6	44·80	23·7
	4858 P.	34·595	18·855	4 6 28·51	90 40 44·9	−2 42·47	−34 17·2	46·04	27·7
5 22 25 42	☄	43·305	14·081						
	4844 A.	44·002	18·607	4 15 45·29	90 9 38·3	+ 13·89	−22 32·4	4 15 59·18	89 47 5·9
	1280 A. G. (1)	43·330	5·125	4 15 58·22	89 2 31·2	+ 0·50	+44 36·1	58·72	7·3
	688 G.	42·100	20·636	4 16 23·39	90 19 47·6	− 24·00	−32 38·7	59·39	8·9
6 22 26 1	☄	43·590	14·086						
	5220 P.	45·387	24·051	4 26 48·84	90 15 23·1	+ 35·80	−49 37 6	4 27 24·64	89 25 45·5
	1329 A. G. (1)	44·295	5·130	4 27 9 81	88 41 7·6	+ 14·04	+44 36 1	23·85	43·7
	725 G.	43·884	11·702	4 27 18·24	89 13 50 6	+ 5·86	+11 49·3	24·10	39 9
	729 G.	40·515	11·164	4 28 25·45	89 11 10·8	−1 1·26	+14 31·1	24·19	41·9

Date G.M.T.	Name of Object.	Rect. Coords. R.A.	Rect. Coords. Dec.	Mean Pos. of stars 1901·0. R.A.	Mean Pos. of stars 1901·0. N.P.D.	$d\alpha$	$d\delta$	Mean Pos. ☄ 1901·0 R.A.	Mean Pos. ☄ 1901·0 N.P.D.
d h m s				h m s	° ′ ″	m s	′ ″	h m s	° ′ ″
May 7 22 24 28	☄	43·059	14·130						
	1378 A. G. (1)	43·360	14·478	4 37 54·03	89 4 47·1	+1 6·00	− 1 44·2	4 38 0·03	89 3 2·9
	1386 A. G. (1)	40·885	11·260	4 38 43·33	88 48 43·6	− 43·31	+14 17·6	0·02	1·2
	5437 P.	38·200	20·924	4 39 37·14	89 36 52·1	−1 36·79	−33 50·0	0·35	2·1
8 22 23 32	☄	43·290	13·910						
	1453 A. G. (1)	45·550	13·852	4 47 5·01	88 39 22·6	+ 45·02	+ 0 16·7	4 47 50·03	88 39 39·3
	1462 A. G. (1)	41·717	18·397	4 48 21·78	89 2 1·8	− 31·34	−22 20·7	50·44	41·1
	1467 A. G. (1)	40·376	13·091	4 48 48·20	88 35 35·1	− 58·07	+ 4 4·7	50·13	39·8
12 22 18 35	☄	43·091	13·910						
	1712 A. G. (1)	45·083	14·751	5 20 0·79	87 10 39·2	+ 39·74	− 4 11·3	5 20 40·53	87 6 27·9
	1720 A. G. (1)	41·092	14·421	5 21 20·43	87 9 2·2	− 39·88	− 2 32·6	40·55	29·6
	1723 A. G. (1)	40·158	12·490	5 21 39·04	86 59 23·9	− 58·51	+ 7 4·3	40·53	28·2
13 22 20 3	☄	43·145	13·895						
	1779 A. G. (1)	47·634	14·438	5 26 2·77	86 46 58·9	+1 29·54	− 2 41·9	5 27 32·31	86 44 17·0
	1797 A. G. (1)	41·891	16·319	5 27 57·63	86 56 22·6	− 25·02	−12 4·3	32·61	18·3
	1801 A. G. (1)	39·125	17·175	5 28 52·74	87 0 38·5	−1 20·20	−16 19·8	32·54	18·7
14 22 44 52	☄	43·165	13·906						
	1834 A. G. (1)	43·460	8·606	5 33 57·52	85 56 6·2	+ 5·88	+26 23·6	5 34 3·40	86 22 29·8
	1835 A. G. (1)	42·590	17·079	5 34 15·20	86 38 17·7	− 11·47	−15 48·1	3·73	29·6
	1849 A. G. (1)	36·652	12·667	5 36 13·71	86 16 22·6	−2 10·06	+ 6 10·8	3·65	33·4

Date G.M.T.	Name of Object.	Rect. Coords. R.A.	Rect. Coords. Dec.	Mean Pos. of stars 1901·0. R.A.	Mean Pos. of stars 1901·0. N.P.D.	$d\alpha$	$d\delta$	Mean Pos. ☄ 1901·0. R.A.	Mean Pos. ☄ 1901·0. N.P.D.
d h m s				h m s	° ′ ″	m s	′ ″	h m s	° ′ ″
May 16 22 27 1	☄	43·110	13·910						
	1913 A. G. (1)	45·055	12·731	5 44 58·63	85 36 20·2	+ 38·86	+ 5 52·3	5 45 37·49	85 42 12·5
	1923 A. G. (1)	42·842	15·041	5 45 43·08	85 47 49·0	− 5·34	− 5 37·6	37·74	11·4
	1928 A. G. (1)	40·420	13·490	5 46 31·30	85 40 4·9	− 53·75	+ 2 5·5	37·55	10·4
19 22 41 13	☄	42·955	13·914						
	2607 A. G. (2)	45·940	11·409	5 59 51·48	84 34 28·9	+ 59·72	+12 28·8	6 0 41·20	84 46 57·7
	2616 A. G. (2)	43·255	7·550	6 0 35·16	84 15 14·9	+ 5·98	+31 42·5	41·14	57·4
	2029 A. G. (1)	36·225	16·644	6 2 56·12	85 0 34·9	−2 14·66	−13 34·9	41·46	60·0
	2031 A. G. (1)	36·035	17·397	6 2 59·98	85 4 22·1	−2 18·46	−17 19·8	41·52	62·3
22 22 56 47	☄	43·245	13·950						
	2772 A. G. (2)	46·210	15·961	6 12 22·34	84 8 42·3	+ 59·38	−10 0·6	6 13 21·72	83 58 41·7
	2781 A. G. (2)	45·073	14·734	6 12 45·16	84 2 34·7	+ 36·63	− 3 54·0	21·79	40·7
	2791 A. G. (2)	42·744	17·836	6 13 32·05	84 18 2·4	− 10·04	−19 22·1	22·01	40·3
23 22 51 8	☄	42·935	14·040						
	2815 A. G. (2)	48·272	19·731	6 15 30·82	84 12 55·7	+1 46·83	−28 19·6	6 17 17·65	83 44 36·1
	2824 A. G. (2)	46·438	10·931	6 16 7·12	83 29 4·1	+1 10·16	+15 29·3	17·28	33·4
	2843 A. G. (2)	43·428	21·657	6 17 8·13	84 22 31·3	+ 9·88	−37 56·0	18·01	35·3
	2860 A. G. (2)	39·435	16·380	6 18 27·83	83 56 12·0	−1 10·08	−11 38·9	17·75	33·1
	2883 A. G. (2)	35·208	3·397	6 19 52·41	82 51 36·1	−2 35·16	+53 1·6	17·25	37·7

Date G.M.T. d h m s	Name of Object.	Rect. Coords. R.A.	Rect. Coords. Dec.	Mean Pos. of stars 1901·0. R.A. h m s	Mean Pos. of stars 1901·0. N.P.D. ° ′ ″	$d\alpha$ m s	$d\delta$ ′ ″	Mean Pos. ☄ 1901·0. R.A. h m s	Mean Pos. ☄ 1901·0. N.P.D. ° ′ ″
May 25 22 37 18	☄	42·960	13·851						
	2939 A. G. (2)	45·520	12·663	6 23 32·50	83 10 25·0	+ 51·38	+ 5 55·2	6 24 23·88	83 16 20·2
	2948 A. G. (2)	42·376	8·440	6 24 35·27	82 49 20·8	− 11·71	+26 56·8	23·56	17·6
	2956 A. G. (2)	41·743	11·071	6 24 48·16	83 2 28·8	− 24·42	+13 50·6	23·74	19·4

d h m	R.A. h m s	N.P.D. ° ′	
Apr. 26 10 1	1 53 50	88 42	Circle readings only, taken when the comet was seen between the clouds for a few seconds only. Probably correct to within about a minute of arc in either coordinate.
31 22 25	3 6 12	90 46	
May 9 22 30	4 57 8	88 6	
11 22 30	5 13 15	87 29	
17 22 30	5 51 18	85 20	
18 22 49	5 56 22	85 2	
20 22 45	6 5 31	84 29	
24 23 31	6 21 15	83 30	
27 23 0	6 31 7	82 51	
30 23 3	6 40 17	82 17	
31 22 59	6 42 36	82 6	

P. = Paris, G. = Greenwich 1880, A. = Argentine Genl., A. G. (1) Astron. Gesell., +1° to +5°, and (2) +5° to +10°.

Perth Observatory: 1901 *June* 24.

Errata in Mr. Cookson's Paper on a Floating Photographic Zenith Telescope

Page 316, line 11, *for* divining *read* devising.
" 322, " 5, *for* $\delta\phi$ *read* $2\delta\phi$.
" 322, " 4 from bottom, *for* ten *read* the.
" 326, " 6, Heading of Table should be:

Mean Diff. Photograph
and Scale in 0·0001 mm.
5 mm. 15 mm.

" 327, " 5 from bottom, *for* degrees *read* grammes.
" 328, lines 1 and 4, *for* degrees *read* grammes.
" 330, line 21 from bottom, *for* but *read* from.
" " " 17 " " *for* and from *read* but for.
" " " 16 " " dele "probable error due to error of."

Errata in Cape Observations of the Great Comet of 1901, *page* 510.

May 4, *for* $29^{s}\cdot23$ *read* $24^{s}\cdot23$.
May 5, *for* $9^{s}\cdot97$ *read* $8^{s}\cdot97$.

INDEX.

APPENDIX.

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LIST OF WORKS
PRESENTED TO THE SOCIETY,
AND OF
WORKS PURCHASED WITH THE TURNOR AND HORROX FUND,
JUNE 1900 TO JUNE 1901.

An asterisk (*) indicates that the work is an excerpt.

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PHOTOGRAPHS, INSTRUMENTS, &c., PRESENTED TO THE SOCIETY.

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MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

APPENDIX TO VOL. LXI.

[*From Proceedings of the Royal Society, Vol. LXVIII.*]

With indication of the original pagination.

No. 1.

CONTENTS.

"Preliminary Determination of the Wave-lengths of the Hydrogen Lines, derived from Photographs taken at Ovar at the Eclipse of the Sun, 1900, May 28." By F. W. DYSON, M.A., Sec. R.A.S. Communicated by W. H. M. CHRISTIE, C.B., M.A., F.R.S. Received January 17,—Read February 7, 1901.

The spectrum of the "flash" obtained in observations of solar eclipses furnishes a method of determining the wave-lengths of the hydrogen series with great accuracy, as these lines are strongly shown and sharply defined. As the determination of these wave-lengths is somewhat removed from the general subject of eclipse spectroscopy, it seemed suitable for a separate paper.

The following determination is made from four photographs taken near the beginning of totality at Ovar, at the eclipse of 1900, May 28,

in the expedition from the Royal Observatory, Greenwich. The spectroscope used is a four-prism quartz spectroscope, kindly lent by Captain Hills. The length of the spectrum from h (λ 4102) to the limit of the hydrogen series (λ 3640) is 40 mm., so that the scale is about 10 tenth-metres to the millimetre.

The spectra were measured with one of the astrographic micrometers of the Royal Observatory (a micrometer originally designed for measuring the photographs taken at the transit of Venus) by comparison with a glass scale divided to millimetres. The errors of the 5-mm. divisions have been accurately determined in the course of investigations of the errors of the réseaux used in the photographic chart of the heavens. The errors of the intermediate divisions were determined by Mr. Davidson. The value of one revolution of the screw of the micrometer is approximately $\frac{1}{3}$ mm.

The wave-lengths were deduced from the measures by an interpolation formula, derived principally from the following lines, whose wave lengths are taken from Rowland's tables :—

Ca	3968·625	Ti.........	3761·464
Ca	3933·825	Ti.........	3759·447
Ti	3913·609	Cr Ti ...	3757·824
Ti	3900·681	Ti.........	3741·791
Mg	3838·435	Ti Fe ...	3722·729
Mg	3832·450	Y	3710·431
Mg	3829·501	Ti.........	3685·339
Y.........	3788·839	Fe Ti ...	3659·901
Y.........	3774·473		

These lines are the strongest lines in this part of the "flash" spectrum. In some of the photographs a number of the strongest iron lines were also used as lines of reference. On the photographs taken a few seconds before the eclipse became total the iron lines are unsuitable as lines of reference, as in some cases both a bright line and an absorption line are seen, and in other cases the lines have a grey appearance, and are not sharp and clear like the lines given above.

The wave-length of h is only derived from one photograph, and is not determined accurately. The value obtained agrees with the result given by Mr. Wright,* in showing a correction of 0·1 of a tenth-metre to the value given by Rowland.

The intensities of the lines are given somewhat roughly. With the exception of the cases noted where other lines apparently interfere, the diminution of intensity is sensibly uniform.

A comparison has been made with the wave-lengths given by Balmer's law, using the formula $\lambda = 3646·140 \frac{n^2}{n^2 - 4}$, the constant of

* 'Astroph. Journ.,' vol. 9.

which agrees very closely with the wave-lengths of the three lines H_α, H_β, H_γ given by Rowland. No correction to the formula has been deduced, as only a small one is indicated, and it is desirable to use a larger number of lines of reference than has been employed in this investigation. The wave-lengths were determined from each series of measures separately, and from the accordance of these the probable errors of the resulting determination of wave-lengths lie between $\pm 0{\cdot}01$ and $\pm 0{\cdot}02$ of a tenth-metre for the different lines.

Hydrogen line.	Int.	*n*.	Observed wave-length.	Wave-length by Balmer's law.	Diff.	Remarks.
δ	40	6	4101·88	·907	+ ·03	Only measured on one photograph.
ϵ	40	7	3970·229	·241	+ ·012	
ζ	60	8	3889·101	·216	—	Helium line at 3888·785 not separated.
η	40	9	3835·540	·550	+ ·010	
θ	30	10	3798·057	·063	+ ·006	
ι	30	11	3770·765	·794	+ ·029	
κ	25	12	3750·322	·315	− ·007	
λ	18	13	3734·565	·531	− ·034	Touching Fe line at 3735·014.
μ	18	14	3722·060	·101	+ ·041	
ν	16	15	3712·109	·133	+ ·024	
ξ	16	16	3703·981	·015	+ ·034	
o	15	17	3697·283	·313	+ ·030	
π	13	18	3691·670	·717	+ ·047	
ρ	11	19	3686·950	·992	+ ·042	
σ	9	20	3682·954	·967	+ ·013	
τ	7	21	3679·483	·514	+ ·038	
υ	6	22	3676·568	·525	− ·043	3676·457 Fe Cr, 3676·698 Co probably interfere.
ϕ	4	23	3673·914	·920	+ ·006	
χ	5	24	3671·574	·638	+ ·064	Probably Zr 3671·412 interferes.
ψ	3	25	3669·595	·625	+ ·030	
ω	1	26	3667·891	·843	− ·048	
α'	2	27	3666·185	·256	+ ·071	
β'	4	28	3664·770	·838	+ ·068	Partly due to Y at 3664·760.
γ'	1	29	3663·565	·553	− ·012	
δ'	5	30	3662·373	·418	+ ·043	Mainly due to Ti at 3662·378.
ϵ'	1	31	3661·475	·380	− ·095	Possibly 6661·509 Fe interferes.

"On the Brightness of the Corona of January 22, 1898. Preliminary Note." By H. H. TURNER, D.Sc., F.R.S., Savilian Professor. Received January 18,—Read February 7, 1901.

1. In a former note* I gave some account of measures of brightness made on photographs of the corona of 1893 by Abney's method. The same method has been used on the coronal photographs taken in 1898 and in 1900 (in 1896 none were obtained owing to cloud), and a large number of measures have been made, though the work is not yet complete. Pending the completion and publication of this work, it seems advisable to publish the present note, as one or two results have been arrived at which may be useful to others in the forthcoming eclipse.

2. As regards the method of measurement, sufficient has been said (for the present purpose) in the paper already quoted. It need only be added that in place of the revolving sectors a graduated wedge of gelatine was used to diminish the comparison beam, according to Sir W. Abney's more recent methods. The wedge or sectors are mere intermediaries between the coronal image and the standard squares, and no considerations beyond those of convenience are involved. The wedge is much more convenient, and the work can be done with it twice as rapidly.

3. But a new method has been adopted of representing the results, which, though an elementary change in some respects, has had the important consequence of suggesting a more satisfactory law for the variation of coronal brightness with distance from the sun. The only simple law (so far as I am aware) which has hitherto been formulated was that proposed by Professor Harkness in 1878, viz. :—

$$\text{Brightness} \propto (\text{distance from sun's limb})^{-2}.$$

Visual measures made by Thorpe and Abney in 1886 and 1893 could not be reconciled with this law; though I showed in the paper already quoted that if the distance be measured from a point *within* the limit (about $\frac{1}{5}$ radius within), the law approximately satisfied the photographic measures.

I have now been led to a completely new law, viz. :—

$$\text{Brightness} \propto (\text{distance from sun's } \textit{centre})^{-6},$$

which, though still on trial, is supported by a fair amount of evidence, and the suggestion arose in the following way :—

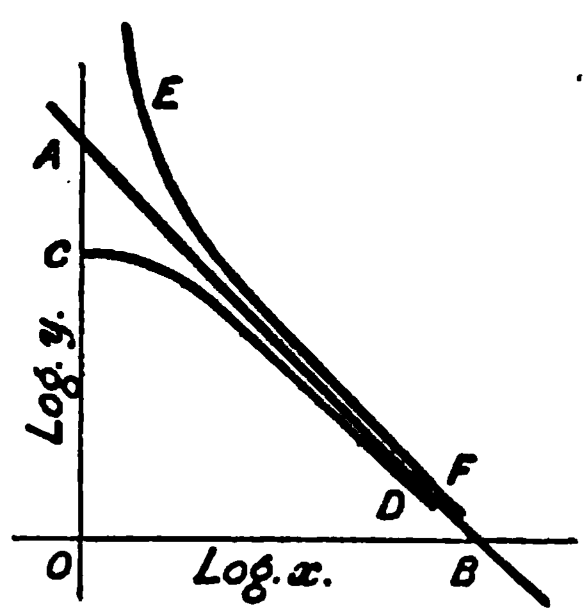
4. The brightness curve in the previous paper was obtained by plotting brightness against distance. This gives a curve of hyperbolic

* 'Roy. Soc. Proc.,' vol. 66, p. 403.

form close to the two axes of reference, and difficult to compare the observations with, for reasons which are tolerably obvious. The curve is still hyperbolic if log (brightness) be plotted against distance; but if the brightness varies as any power of the distance, and we plot log (brightness) against log (distance), we get a straight line, which is particularly easy to compare observations with. The only difficulty is that we must know where to measure our distance from; for if we add or subtract a constant to the distance, it will change the straight line into a curve. And unfortunately the point from which the distance was to be measured seemed just one of the things to be determined.

5. But after some preliminary experiments I found that it was not difficult to find the proper origin from which to measure the distance, by the very condition that the curve was to be a straight line.

Fig. 1.



If in the equation

$$\log y + n \log x = \text{const.}$$

represented by the straight line AB in fig. 1, we write $(x + \alpha)$ for x, then the calculated values of $\log y$, when x is large compared with α, will be nearly the same as before; but when x is small $\log (x + \alpha)$ will be increased, and $\log y$ therefore diminished, and we get a curve such as CD. (If α be negative, we get a curve such as EF.) And a very few trials (perhaps one alone suffices) give the value of α, which will straighten the curve.

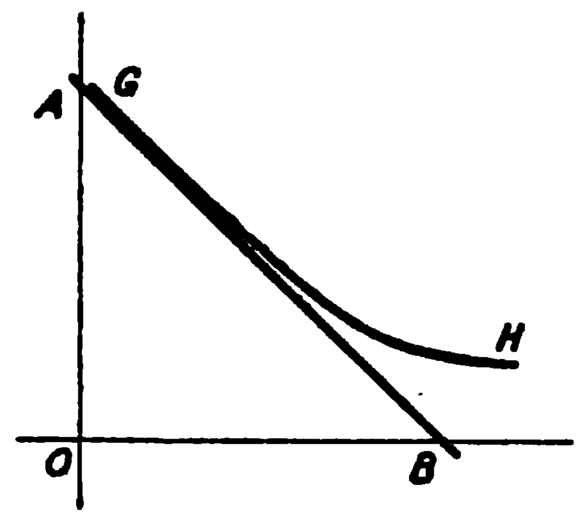
6. These values immediately pointed to the sun's centre as the proper origin for measurement; and when the observations were plotted on this assumption, the curve was practically a straight line, and the slope of this line indicated that the index n was 6, giving the law already stated, viz.:—

$$\text{Brightness} \propto (\text{distance from sun's centre})^{-6}.$$

7. But one further point is to be noted. The curve was practically straight for some distance from the limb, but then always turned

upwards like the curve GH in fig. 2. Now comparing this with CD in fig. 1, it suggests that just as CD could be explained by the addition of a constant to the *distance*, which made a variable alteration in the log distance, so GH may be explained by the addition of a constant to

FIG. 2.



the *brightness*, making a variable alteration in the log brightness. And there is a possible physical cause for this constant addition, viz., the general sky illumination or glare which is added to the coronal brightness. A value of about 0·012 of the average brightness of the full moon for this illumination seems to satisfy requirements for the 1898 photographs.

8. I proceed to give a brief summary of the measures on the photographs of 1898 so far as they have gone.

Four photographs have been selected for measurement, three of them taken by me at Sahdol with exposures of 1 sec., 2 secs. and 20 secs., and one taken by Capt. Hills at Pulgaon with exposure 8 secs. On these, measures have been made along six radii extending approximately N., S., E., W., N.E., and S.W., the last two being as nearly as possible in the direction of the main streamers.

9. The exposures given to the standard squares were all the same. These squares transmit fractions of the light ranging from 0 to 4 on a scale of powers of 2, a range which might be extended with advantage, seeing that measures on the corona can be profitably made over a range of 0 to 7 at least. But the smallness of the range is made up for in practice by the measurement of photographs with different exposures. Thus the longer exposures of 20 secs. and 8 secs. in the above series control the fainter parts of the corona, and the shorter of 1 sec. and 2 secs. control the brighter parts near the limb.

10. In comparing the results from the different plates, it is found that the brightnesses shown by one plate differ from those shown by another in a constant *ratio*. Since the log (brightness) is tabulated this means a constant *difference* between similar numbers for the two plates. Following Sir W. Abney's practice, I have used the base 2 for the logarithms of brightness, and recorded to 0·1, which represents a

ratio of $2^{0\cdot1} = 1\cdot07$. (The logarithms of distance have been taken to base 10 in the ordinary way.) These differences between the plates may be due to any combination of the following causes:—

(*a.*) Accidental error in exposure to corona. The exposures were made without any mechanism, and the short ones especially may be sensibly in error. Thus the difference between the 1 sec. and 20 secs. exposure is 0·8. If the whole of this be due to accidental error in the 1 sec. exposure, it would mean that the exposure was for 1 sec. $\times\ 2^{-0\cdot8}$ $= 0\cdot58$ sec. instead of for 1·0 sec., which is not an extravagant supposition.

(*b.*) Accidental error in exposure to squares. This should be much smaller than (*a.*).

(*c.*) Difference in sensitiveness of the film near the edge of the plate where the squares are impressed, and in the centre where the corona is impresssed. There is independent evidence of sensible differences of this kind, and the point is under investigation.

(*d.*) Differences in the behaviour of the candle which impressed the squares on the various plates.

(*e.*) Climatic differences between Sahdol and Pulgaon.

11. It becomes necessary to decide which plate to take as the standard. Cause (*a.*) ought not to affect the 8 secs. and 20 secs. appreciably, but cause (*e.*) may. They differ by 0·5, and we may perhaps take the mean. The corrections to be applied to the plates are then

Plate	I	II	III	IV
Exposure......	1 sec.	2 sec.	8 sec.	20 sec.
Place	Sahdol	Sahdol	Pulgaon	Sahdol
Correction ...	+0·6	−0·2	+0·3	−0·2

If any other selection is preferred, it is easily applicable as a constant to the final numbers.

12. The correction for constant illumination of the plate due to sky-glare has been adopted as $2^{-6\cdot4}$ moon, taking the moon as equal to 0·02 of a candle at 1 foot. If at any point the corona has a brightness represented by x, meaning $2^x \times$ moon, then the brightness measured on the plate will appear as y where

$$2^x + 2^{-6\cdot4} = 2^y.$$

A table was formed giving y in terms of x, of which the following is a portion:—

x.	Correction to x.	y.
$-2\cdot0$	$0\cdot0$	$-2\cdot0$
$-3\cdot0$	$+0\cdot1$	$-2\cdot9$
$-4\cdot0$	$+0\cdot2$	$-3\cdot8$
$-5\cdot0$	$+0\cdot4$	$-4\cdot6$
$-6\cdot0$	$+0\cdot8$	$-5\cdot2$
$-7\cdot0$	$+1\cdot3$	$-5\cdot7$
$-8\cdot0$	$+2\cdot0$	$-6\cdot0$

13. The measures on the plates were then corrected—

(*a.*) For the particular plate, as in § 10;
(*b.*) For the sky-glare, as in § 11;

and compared with the curve

$$\text{brightness} \times (\text{distance})^6 = \text{A}$$

to get the value of the constant A for each of the six radii measured. As above explained, the curve used was a straight line, obtained by plotting log brightness as ordinate and log distance as abscissa. The constants found for the six radii were as follows—adopting as unit of brightness that of the moon (assumed 0·02 candle at 1 foot), and of distance that of the sun's radius, so that the constants represent the brightness of the corona at the sun's limb expressed in moons:—

Radius.	N.	N.E.	E.	S.	S.W.	W.	Mean.
A =	+0·4	+1·9	+1·7	0·0	+2·3	+0·6	+1·15

Thus at the sun's limb the corona is more than twice as bright as the full moon on the average.

14. Finally, the individual measures were compared with the adopted law, with the following results. In the column "Typical Curve" the calculated brightness is given for A = + 0·6, the actual figures for the different streamers differing from this throughout by constants which are easily inferred from the values of A given above.

Table I.—Comparison of Observed Brightness (Photographic) of 1898 Corona with the Law.

Brightness × (distance from Sun's centre)^6 = constant.

(The distances were measured in divisions of 13 to the Sun's radius. The brightnesses are expressed by powers of 2, zero representing Moon's brightness.)

Distance from Sun's centre in radii.	Typical brightness of corona alone.	Typical brightness with "glare" added.	Plate.	Observed error of formula.					
				N.	N.E.	E.	S.	S.W.	W.
1·08	+ 0·1	+0·1	I	+0·6	—	−0·1	+0·7	—	+0·4
1·15	− 0·4	−0·4	I	+0·6	−0·1	0·0	+0·4	−0·7	+0·4
1·23	− 1·0	−1·0	I	+0·2	—	−0·1	+0·2	−0·4	0·0
1·31	− 1·5	−1·5	I	+0·5	+0·1	+0·2	−0·2	−0·3	+0·1
1·38	− 2·0	−2·0	I	−0·4	—	0·0	0·0	0·0	+0·1
1·46	− 2·5	−2·4	I	0·0	+0·1	−0·5	+0·3	−0·1	−0·1
1·61	− 3·3	−3·1	I	−0·3	−0·5	−0·7	—	0·0	—
1·77	− 4·1	−3·8	I	—	−0·1	—	—	+0·2	—
1·92	− 4·9	−4·4	I	—	−0·1	—	—	+0·2	—
1·31	− 1·5	−1·5	II	+0·3	—	—	−0·1	—	—
1·38	− 2·0	−2·0	II	0·0	—	—	−0·3	—	+0·2
1·46	− 2·5	−2·4	II	−0·2	—	—	−0·5	—	−0·1
1·54	− 2·9	−2·8	II	−0·3	+0·5	+0·6	−0·3	—	−0·2
1·61	− 3·3	−3·1	II	−0·4	+0·1	+0·2	−0·3	+0·3	−0·2
1·77	− 4·1	−3·8	II	−0·2	−0·2	+0·1	−0·1	−0·1	−0·1
1·92	− 4·9	−4·4	II	—	−0·2	+0·1	—	+0·1	—
2·15	− 5·8	−5·1	II	+0·1	−0·3	+0·1	—	+0·2	—
2·54	− 7·2	−5·8	II	—	—	—	—	+0·3	—
1·46	− 2·5	−2·4	III	0·0	—	—	+0·1	—	—
1·61	− 3·3	−3·1	III	0·0	—	—	+0·1	—	0·0
1·77	− 4·1	−3·8	III	+0·1	+0·4	+0·2	+0·1	0·0	−0·1
1·92	− 4·9	−4·4	III	−0·1	+0·2	+0·2	+0·1	+0·1	−0·2
2·15	− 5·8	−5·1	III	−0·1	0·0	−0·1	+0·1	0·0	0·0
2·54	− 7·2	−5·8	III	+0·2	+0·2	+0·1	—	0·0	0·0
2·92	− 8·5	−6·1	III	—	+0·4	0·0	—	−0·1	—
1·92	− 4·9	−4·4	IV	+0·1	—	—	+0·3	—	—
2·08	− 5·5	−4·9	IV	+0·2	−0·4	—	+0·4	—	+0·4
2·23	− 6·1	−5·3	IV	+0·2	−0·2	0·0	+0·4	—	+0·2
2·38	− 6·7	−5·6	IV	—	−0.2	+0·1	—	0·0	+0·2
2·54	− 7·2	−5·8	IV	+0·2	−0·2	0·0	+0·5	0·0	+0·2
2·92	− 8·5	−6·1	IV	−0·1	−0·2	+0·1	+0·3	0·0	+0·3
3·31	− 9·6	−6·3	IV	—	−0·1	+0·1	+0·1	−0·1	0·0
3·69	−10·5	−6·3	IV	—	−0·2	0·0	—	−0·3	—
4·08	−11·4	−6·4	IV	—	−0·4	—	—	−0·3	—

15. Considering the irregularity of the coronal structure, we cannot perhaps expect better agreement with any simple law of brightness than is shown by these residuals; and the assumed law, whether it has

any physical significance or not, is, at any rate, a convenient method of expressing the facts. We may now turn to the measures previously given of the 1893 corona,* and see how they accord with this formula. On trial, it is found that a fair accordance can be secured if the constant correction for sky-glare be taken as $2^{-7.8}$ instead of $2^{-6.4}$, and the constants for the four radii measured be

N.	S.	E.	W.	Mean.
−0·1	+0·4	+0·5	+0·1	+0·23

16. With regard to the smaller value for sky-glare, if this depends on the general brightness of the corona itself, we may remark that the 1893 corona was generally fainter, according to the measures, than the 1898 corona, the mean constant for the former being + 0·23, and for the latter + 1·15. The difference is + 0·92, so that the 1898 corona was about twice as bright, and hence twice as bright a sky illumination is not unreasonable.

Table II.—Comparison of Observed Brightness (Photographic) of 1893 Corona with the Law.

Brightness × (distance from Sun's centre)^6 = constant.

(The distances are given in units of the Sun's radius. The brightnesses are expressed by powers of 2; zero representing the Moon's brightness.)

Distance from Sun's centre.	Typical brightness of corona alone.	With "glare" added.	Observed error of formula.			
			N.	S.	E.	W.
1·1	+0·2	+0·2	—	−0·9	—	—
1·2	−0·6	−0·6	−0·1	−0·4	—	—
1·3	−1·2	−1·2	—	−0·1	—	+0·1
1·4	−1·9	−1·9	+0·4	+0·4	−0·3	+0·3
1·5	−2·5	−2·5	+0·2	+0·4	—	+0·5
1·6	−3·0	−2·9	0·0	+0·3	—	—
1·7	−3·6	−3·5	−0·1	+0·4	—	+0·3
1·8	−4·1	−4·0	0·0	+0·2	+0·5	+0·1
1·9	−4·6	−4·4	−0·2	+0·1	—	0·0
2·0	−5·0	−4·8	−0·2	−0·1	—	—
2·1	−5·4	−5·2	−0·2	−0·2	—	−0·3
2·2	−5·8	−5·5	−0·1	−0·2	−0·2	−0·7
2·3	−6·2	−5·8	−0·3	−0·3	—	0·0
2·4	−6·6	−6·1	+0·2	−0·1	—	—
2·5	−7·0	−6·3	+0·1	0·0	—	0·0
2·6	−7·3	−6·5	+0·3	0·0	0·0	+0·1
2·7	−7·6	−6·7	—	+0·1	—	−0·1
2·8	−7·9	−6·8	+0·3	−0·1	—	—
2·9	−8·2	−7·0	—	−0·1	—	+0·1
3·0	−8·5	−7·1	+0·3	−0·1	0·0	+0·1

* 'Roy. Soc. Proc.,' vol. 66, p. 403.

17. The discrepancies are again not large, and some of them may be due to the extrapolation which was necessary for the brighter parts of the corona, the standard squares not having been given a long-enough exposure (as stated in the former paper) to compare with the long exposure of 50 secs. to the corona. Measures on plates with a shorter exposure to the corona will perhaps allow of more accurate results near the sun's limb. Unfortunately no plate is available with an exposure shorter than 5 secs., but measures on this plate, so far as they have gone, indicate a closer accordance with the theoretical formula near the limb. Further measures are, however, required.

18. With the assumed law

$$\text{brightness} = \mathrm{A}r^{-6},$$

where r represents distance from the sun's limb in solar radii, the total brightness of the corona is

$$\int_1^\infty \mathrm{A}r^{-6} \times 2\pi r dr = \tfrac{1}{2}\pi\mathrm{A},$$

the total brightness of the full moon being represented by

$$\int_0^1 2\pi r dr = \pi.$$

Thus the ratio of the total brightness to that of the moon is $\frac{1}{2}$ A. In 1898 the value of A was approximately $2^{1\cdot15} = 2\cdot2$, and thus the whole corona was about equal to the full moon. In 1893 the value of A was $2^{0\cdot23} = 1\cdot2$; and the whole corona was thus about 0·6 of the full moon.

19. But we have omitted the constant illumination of the sky in this integral. If we include a portion of sky extending to distance R from the limb, and B be the value of the constant for "glare," which in 1893 was taken as $2^{-7\cdot8} = 0\cdot0046$, and in 1898 was $2^{-6\cdot4} = 0\cdot012$, then we must add to the above quantities

$$\frac{1}{\pi}\mathrm{B}\int_1^{\mathrm{R}} 2\pi r dr = \mathrm{B}(\mathrm{R}^2 - 1) \text{ full moon.}$$

It is not, however, easy to assign a definite value to R.

20. The integral brightness of the corona was measured in 1893 by the late Mr. James Forbes, jun.,* and found to be 1·1 full moon. We find $[0\cdot6 + \mathrm{B}(\mathrm{R}^2 - 1)]$ full moon.

If the two quantities be equated, we get

$$\mathrm{B}(\mathrm{R}^2 - 1) = 0\cdot5$$

or

$$\mathrm{R}^2 = 0\cdot5/0\cdot0046$$
$$= 110$$

or

$$\mathrm{R} = 10\cdot5.$$

* 'Phil. Trans.,' A, 1896, p. 433.

Thus, if we suppose that Mr. Forbes measured the total light within a circular area 5° in diameter, which seems a fair supposition,* the two measures of total brightness agree.

On the same supposition, the value of B $(R^2 - 1)$ in 1898 would be 1·3 full moon, and the total brightness of the corona would appear as $1{\cdot}1 + 1{\cdot}3 = 2{\cdot}4$ full moon.

Summary.

(*a*.) The brightness of the corona of 1898 at a point distant r from the sun's *centre* expressed in solar radii may be approximately represented by the formula

$$\text{brightness} = Ar^{-6} + B,$$

where A and B are constants.

(*b*.) The first term may be considered as corona proper, while B may be taken as representing the constant illumination of the sky, or glare. In 1898 the value of B was $2^{-6{\cdot}4} = 0{\cdot}012$ moon, taking the brightness of the moon as 0·02 candle at 1 foot.

(*c*.) The constant A varies with the radius along which measures are made. In 1898 it varied from $2^{0{\cdot}0}$ moon to $2^{1{\cdot}9}$ moon, the mean being $2^{\cdot 115}$ moon or 2·2 moon.

(*d*.) The same formula will fairly represent the 1893 corona, the mean value of A being $2^{0{\cdot}28} = 1{\cdot}2$, and the value of B $2^{-7{\cdot}8} = 0{\cdot}0046$.

(*e*.) The total brightness of the corona depends on the area of sky included. If a circular area 5° in diameter be included, the total brightness of the 1893 corona may be taken as 1·1 full moon, agreeing with the visual measures made, and that of 1898, on the same supposition, would be about 2·4 full moon.

* The dimensions of the box are not given, either here or in the previous paper to which we are referred; but on p. 369 of the 'Philosophical Transactions,' A, 1889, there is a diagram of the box, from which it would appear that the angular aperture was not greater than 12°, judging by outside measurements.

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CONTENTS.

"The New Star in Perseus.—Preliminary Note." By Sir NORMAN LOCKYER, K.C.B., F.R.S. Received and Read February 28, 1901.

Dr. Copeland was kind enough to inform me by telegram on the afternoon of February 22, of the discovery by Dr. Anderson of a new star in the Milky Way in Perseus on the early morning of that day. It was stated that its position was R.A. $3^h\ 24^m\ 25^s$ and Declination $+43°\ 34'$, its magnitude 2·7, and colour of a bluish-white. Later in the evening this information was corroborated by another telegram from the "Centralstelle" at Kiel.

Owing to cloudy weather, no photographs could be obtained at Kensington until the evening of the 25th. Momentary glimpses of the star on the evening of the 22nd, between the hours of 6 and 7.30 P.M., indicated that the Nova had considerably brightened since the time of its discovery, as it was estimated as a little brighter than a 1st magnitude star; no satisfactory observations of the spectrum could be made. Another glimpse on the early morning (1.30 A.M.) of Monday (25th) showed that the star was still of about the 1st magnitude.

Professor Pickering reports that the Nova was dimmer than an 11th magnitude star on February 19. On the 23rd it was as bright as Capella. The star, therefore, was then at least 10,000 times brighter than it was four days previously, and ranks as the brightest new star recorded since that which appeared in the year 1604.

Since the 25th the brightness has diminished slightly, and on the evening of the 27th was estimated between the 1st and 2nd magnitude (1·7). If this reduction of brilliancy continues at the same rate, the new star will evidently be shorter lived than those to which it has most closely approximated in luminous intensity at the maximum, and less time will be available for studying the spectral changes which may be anticipated. I may state that Tycho's Nova (1572) was visible for nearly 1½ years, and Kepler's (1604) for about the same period.

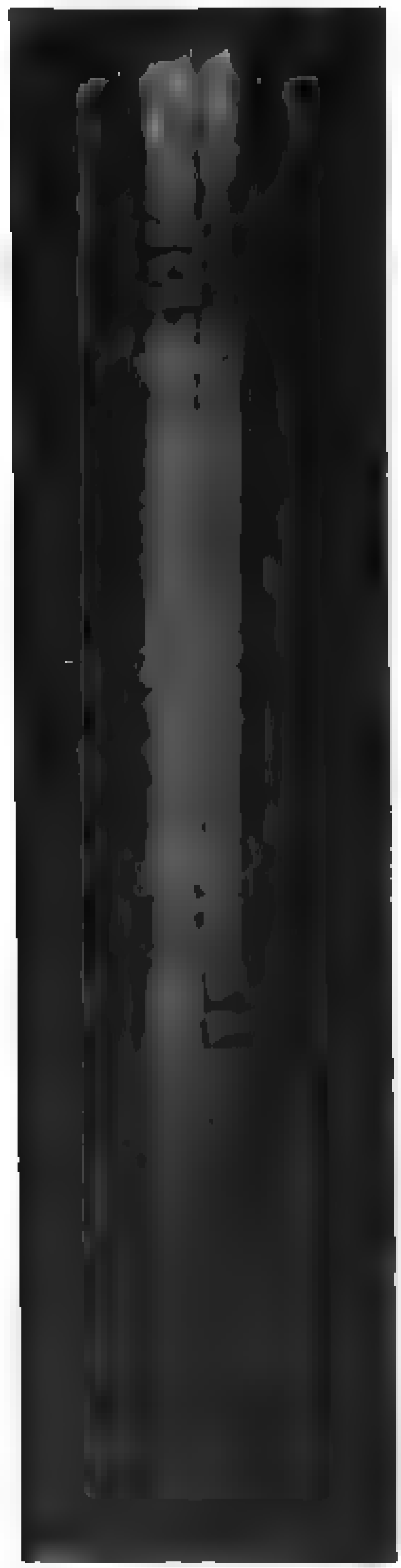
It is interestiug to note that the star was described by Dr. Anderson as being of a bluish-white colour at the time of discovery. Since it has diminished in brightness this has changed, and on the night of February 27, a reddish tinge was observed.

The sky on Monday evening was by no means free from clouds, but ten very satisfactory photographs were secured with the three instruments in regular use for stellar spectra. Edwards's isochromatic plates were used, as it was considered desirable to secure a record of the green part of the spectrum.

Although there has not been time for a complete discussion of these photographs, it may be stated that the spectrum contains numerous dark lines, several of which are associated with bright bands on the

less refrangible side. Further, the spectrum, as a whole, greatly resembles that of Nova Aurigæ.

(A) (B)



(A). Spectrum of Nova Persei.
(B). „ „ α Persei, photographed on the same plate.

Taken with a 30-inch common reflector and a two-prism slit spectroscope.

One of the chief features of the principal bright lines is their great width, amounting to 30 tenth-metres, and each is accompanied by a dark line of considerable breadth on its more refrangible side. A comparison spectrum of γ Orionis, photographed alongside that of the Nova on one

of the plates, indicates that the middle portions of the bright lines are not far from their normal positions; those of the dark ones, however, are displaced by some 15 tenth-metres towards the violet, thus indicating a differential movement of something like 700 miles a second.

Movements more rapid and disturbances more violent than those observed in Nova Aurigæ are therefore indicated; both by the greater displacement of the dark lines relatively to those that are bright and the greater breadth of the bright and dark lines.

The comparison of spectra shows us that we are dealing with two swarms, one of which, the less dense, gives us broad bright lines and is almost at rest with reference to the line of sight; the denser swarm, indicated by the dark lines, is in most rapid movement in the line of sight towards the earth.

An interesting feature of the spectrum is the presence of fine dark lines down the middle of each of the bright lines of hydrogen and calcium; these are most probably reversals, and if this be so, they will be of great service for accurate determination of the wave-lengths of the other bright lines. The dark hydrogen line $H\gamma$, and perhaps $H\beta$ and $H\delta$, are also possibly reversed.

Eye observations showed among the chief lines a group of four in the green; one probably $H\beta$, the others near $\lambda\lambda$ 492, 501, and 517; a bright line at or near D, and a brilliant red line probably corresponding to $H\alpha$. Each of these was accompanied by a dark broad line on its more refrangible side. Other lines of less brightness were observed both in the green and red.

It at first seemed probable that two of the bright lines in the green ($\lambda\lambda$ 492 and 501) might be due to asterium, while that in the orange was perhaps the helium line D_3. Subsequent investigation, however, suggested as an alternative origin that these lines might be the enhanced lines of iron at λ 4924·1 and 5018·6, which are very nearly in the same positions as the asterium lines. This view was tested by inquiring whether other prominent enhanced lines of iron so strongly visible in the spectrum of α Cygni were present.

A comparison with the spectrum of this star photographed with the same instruments suggested that many lines between F and *h* in the Nova probably correspond with lines in α Cygni. Certainty could not be arrived at in consequence of the great breadth of the lines in the Nova.

Hence, as the Nova bore some resemblance to both Nova Aurigæ and α Cygni, a reference was suggested to the lines recorded in the spectrum of Nova Aurigæ which were observed when the light of that star was on the wane, and when the lines were thinned enough to be easily measurable. I may also add that these observations were made before the work on enhanced lines was undertaken.

The importance of this reference was strengthened by the considera-

tion that with such a tremendous outburst we should expect the original invisible swarm to have been (very rapidly) advanced to a considerable condensation at the locus of impact, and therefore to resemble some "star" which had (slowly) arrived at a position pretty high up on the ascending temperature curve in the ordinary course of evolution on the meteoritic hypothesis.

A comparison of the bright lines recorded by Campbell* and Vogel† in the spectrum of Nova Aurigæ with the strongest lines of α Cygni—a very detailed record of the spectrum of which star has been recently compiled here—shows that there is a close agreement between the two sets of lines. These strong α Cygni lines are almost without exception the representatives of "enhanced" lines of some of the metals, chiefly Fe, Ti, Cr, Ni, Ca, Sr, and Sc. If we exclude the lines of hydrogen from those which were recorded in the spectrum of Nova Aurigæ, there remain forty-four lines for comparison. Thirty of these, or about ·70 per cent., agree approximately in position with either strong isolated lines or groups of lines in the spectrum of α Cygni.

It may be assumed that, taking into consideration the broad nature of the Nova lines, if there be any genuine connection between them and the lines of α Cygni, any close groups of separately distinguishable lines in the latter spectrum would be thrown together in the Nova spectrum, and appear as broad bands. A good instance of this appears in Campbell's list. He records a band extending from $\lambda\lambda$ 4534 to 4501. In the spectrum of α Cygni there is a strong line at each of the positions given, and between them there occurs a strong quartet of lines. The former are well enhanced lines of titanium, and the latter of iron. It seems extremely likely, therefore, that the six lines thrown together produce the apparently continuous band observed by Campbell.

If the stage of α Cygni has really been reached, the following considerations come in:—

In the orderly condensation of swarms, according to the meteoritic hypothesis, the earlier stages are—

Ascending temperature.

Cygnian	Dark lines, corresponding chiefly with the enhanced lines of various metals.
Polarian	Dark lines, comprising both arc and enhanced lines of various metals.
Aldebarian	Dark lines, chiefly corresponding to those which appear in the arc spectra of various metals.
Antarian	Mixed bright and dark flutings and dark lines. Bright lines of hydrogen in those stars which are variable.
Nebula	Bright lines.

* 'Ast.-Phys. Jour.,' vol. xi, p. 807, 1892.

† 'Ast.-Phys. Jour.,' vol. xii, p. 912, 1893.

In the case of new stars, after the maximum of luminosity has been reached, however high they ascend, short of the apex of the temperature curve, this order must be reversed, and hence we should expect to find the spectrum varying in accordance with the foregoing sequence, but in the reverse order.

In Nova Coronæ (1866), according to the observations of Sir William Huggins and Dr. Miller, the absorption spectrum was very similar to that of α Orionis, which is a star of the Antarian group, so that the temperature attained was relatively low; this indeed is demonstrated by the fact that at present it shines faintly as an Antarian star, and doubtless did so before the collision. The collision, therefore, probably did not take Nova Coronæ very much above its initial stage of temperature, and when the disturbance was over it simply reverted to its old conditions.

The spectrum of Nova Cygni (1876) was not photographed, and as special attention was given by most observers to the bright lines, there is no satisfactory record of the absorption spectrum.

This now appears as a nebula, and doubtless it was a nebula to begin with, as Nova Coronæ was a star to begin with.

In Nova Aurigæ (1892), as we have seen, the comparison with α Cygni indicates that the Cygnian (a higher) stage was reached, and in the final stages its spectrum corresponded with that of the planetary nebulæ, that is, a stage lower than that reached by Nova Coronæ. The intermediate stages, however, were not observed, possibly because the star was never very brilliant, and partly because of the difficulty of observing closely grouped lines, such as occur in the Polarian and Aldebarian stages when they are rendered broad by such disturbances as those which were obviously present in the Nova.

The observed maximum magnitude in the case of a new star will evidently depend upon the distance and size of the colliding masses, as well as upon the temperature produced by the collision. It is not remarkable, therefore, that there is no apparent relation between the greatest brightness and the temperature indicated by the spectra. Nova Coronæ, with its relatively low temperature, shone for a time as a 2nd magnitude star, while Nova Aurigæ, with a much higher temperature, scarcely surpassed a star of the 5th magnitude.

I now return to Nova Persei. If the idea that in the present Nova the swarm which gives the dark line spectrum resembles α Cygni be confirmed; as its temperature is reduced we may expect it to pass successively through some or all of the stages of temperature represented by stars of the Polarian, Aldebarian, and Antarian groups, enhanced lines being first replaced by arc lines, and then by flutings. Whether it remains at one of these stages or undergoes a further backwardation into a nebula will be a point of the highest interest.

If, like Nova Aurigæ, the present Nova should end as a nebula, it

will furnish a most convincing proof of the fundamental metallic nature of nebulæ.

In conclusion, I wish to express my thanks to Dr. W. J. S. Lockyer and Mr. F. E. Baxandall, of the Solar Physics Observatory, and to Mr. A. Fowler, of the Royal College of Science, who have greatly assisted me in preparing the present note, and who, with the addition of Mr. Butler, of the Solar Physics Observatory, secured the excellent set of photographs and eye observations on the night of the 25th, from which the new knowledge has been derived.

The preparation of the slides I owe to Sapper J. P. Wilkie.

"Further Observations on Nova Persei." By Sir NORMAN LOCKYER, K.C.B., F.R.S. Received and Read March 7, 1901.

[PLATE 1.]

Since the preliminary note on this star was communicated to the Royal Society on February 28th, observations have been possible on the nights of February 28th, March 1st, 3rd, and 5th, and twenty-four photographs of the spectrum have been taken with the instruments before detailed.

It may be stated generally that the light is slowly waning. On February 28th the star was only slightly brighter than α Persei. On March 1st it was estimated as about equal to α Persei, *i.e.*, about 2·0 magnitude. When it was again visible on the evening of March 3rd, it was distinctly less bright than β Persei, and its magnitude probably near 2·5; on the 5th its estimated magnitude was 2·7.

The above refers to the visual brightness. A photograph of the region occupied by the Nova on March 3rd showed it to be photographically brighter than α Persei.

General Description of the Spectrum.

The photographs show that the bright hydrogen lines are successively feebler as the ultra-violet is approached, and the whole of the series of hydrogen lines have during the past week become relatively brighter with respect to the remaining lines and the continuous spectrum. The spectrum extends far into the ultra-violet.

Among the changes which have taken place in the visible part of the spectrum, it may be mentioned that while the lines of hydrogen have become relatively brighter during the past week, the remaining lines, with the possible exception of the prominent one at λ 5169, have become distinctly dimmer. There has also been a diminution of the intensity of the continuous spectrum. The line in the yellow, the identity of which has not yet been definitely determined, has gradually decreased in intensity with the diminution of brightness of the star.

In the visible part of the spectrum the bright green-blue F line of hydrogen has become more conspicuous as the neighbouring green lines have become fainter, and the bright C line is intensely brilliant.

From all these causes, which give us blue light on the one hand and red on the other, the star should present to us the precise quality of red which has been observed.

Colour.

At discovery the star was described as bluish-white. No observations on its variation in hue during its brightening were possible, owing to unfavourable weather conditions. The observations during the period of decline have indicated a change to the present colour of a decided claret red. In comparison with this, it is interesting to note that in the case of the Nova which appeared in 1604, Kepler alludes to purple and red tints assumed by the star.

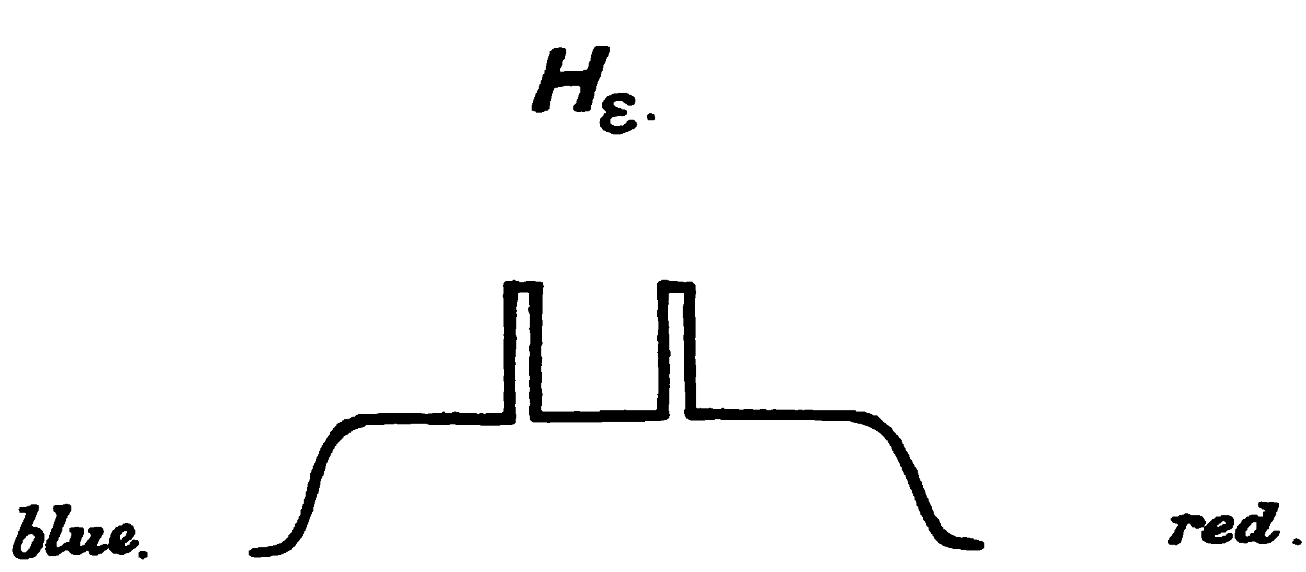
Changes in the Photographic Spectrum.

Between February 25th and March 5th, to take the extreme difference of dates on which photographs were obtained, it has been noted that while some of the dark lines were absent at the later date, either new lines had come in or previously feeble lines had become intensified. There has not yet been time to determine accurately the positions of these lines (see Plate 1).

The appearance of the bright lines of hydrogen which I described as being reversed on February 25th, had very materially changed by March 3rd.

In inspecting the dark band representing the bright hydrogen at Hϵ, two darker fine lines are seen nearly coincident in position with the edges of Hϵ in the spectrum of α Persei.

To my eye the light curve is as follows:—



The appearance is different in the case of the F line (Hβ), a light curve of which I also give—

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The best star for this purpose is α Cygni, but unfortunately no good photograph has been obtained at Kensington of the green portion of the spectrum of that star. The star most nearly approaching α Cygni in relation to enhanced lines is α Canis Majoris, which in the Kensington classification has been placed nearly on a level with the former star, but on the descending side of the temperature curve. In the spectrum of this star the enhanced lines of iron $\lambda\lambda$ 4924·11, 5018·63, $\left\{\begin{array}{l}5169{\cdot}07\\5169{\cdot}22\end{array}\right.$ and 5316·79 occur as well-marked lines. This spectrum has been directly compared with that of Nova Persei taken with the same instrument, and the fact that all the lines apparently coincide, affords good evidence that the connection is a real one, and that the first four strong Nova lines beyond F on the less refrangible side are the representatives of the enhanced lines of iron. These are the only enhanced lines which occur in that part of the iron spectrum, with the exception of a weak one at λ 5276·17. There is only a trace of this line in the spectra of either the Nova or α Canis Majoris which have been compared. In the spectra of the Nova obtained with lower dispersion, however, a line is distinctly shown in this position, though it is considerably weaker than the four lines previously mentioned.

The absence of the strong lines which are familiar in the arc spectrum, and in the ordinary spark spectrum in this region, is to be ascribed to higher temperature; experiments which are in progress show that under certain conditions, the two lines λ 5018·6 and λ 5169 are by far the strongest lines in the spectrum of iron between λ 500 and D, while that at λ 4924·1 is distinctly stronger than any of the well-known group of four arc lines in which it falls.

The published wave-lengths of the lines of Nova Aurigæ show that the same lines were present in that star. Further investigations of the spectrum of Nova Aurigæ have strengthened the conclusion that most of the lines, after we pass from those of hydrogen, are enhanced lines of a comparatively small number of metals.

When the inquiry is extended into the region more refrangible than Hβ, the evidence in favour of the similarity of the spectra of the two Novæ with that of α Cygni is not so conclusive, because of the greater breadth of the lines (since the spectra have been obtained by the use of prisms) and because of the fact that in this region the enhanced lines of iron frequently occur in groups.

In the region between Hδ and Hγ, however, there is a well marked enhanced line of iron at λ 4233·3 and also two doubles at $\lambda\lambda$ 4173·7, 4179·0, and $\lambda\lambda$ 4296·7, 4303·3, and a comparison of α Cygni with Nova Persei indicates that these fall on broad bright bands of the Nova spectrum.

It is not claimed that all the enhanced lines which appear in the spectrum of α Cygni are represented in that of Nova Aurigæ. There

is, however, a sufficient reason why at a particular stage in the spectrum of such Novæ the enhanced lines of certain substances should predominate. Thus, in γ Cygni, titanium is most strongly represented by enhanced lines; in α Cygni, iron, chromium, and nickel; in β Orionis, silicium and magnesium, and so on. We may thus expect to find the lines of different substances most prominent at different stages in the history of the star.

In the work above referred to I have been assisted as follows:— The new photographs have been taken by Dr. Lockyer and Messrs. Fowler, Baxandall, Shackleton, Butler, Shaw, and Hodgson. The detailed examination of the photographs has been made by Messrs. Fowler and Baxandall. The visual observations have been chiefly made by Messrs. Fowler and Butler. The photographs have been enlarged and the illustrations for this paper prepared by Sapper Wilkie. To all, my best thanks are due.

"On the Enhanced Lines in the Spectrum of the Chromosphere." By Sir NORMAN LOCKYER, K.C.B., F.R.S., and F. E. BAXANDALL, A.R.C.S. Received March 19,—Read March 28, 1901.

In the recently published account* of the spectroscopic results obtained by members of the expedition from the Yerkes Observatory, during the solar eclipse of May 28th, 1900, although the record of the wave-lengths of the lines photographed on the different eclipse plates is of great value, exception must be taken to the method of assigning origins to the lines. This question is so important just now that it is desirable to deal with it without delay. The only origins which Professor Frost appears to accept are those given by Rowland to any moderately strong solar line which agrees in position, either exactly or very nearly, with an eclipse line. In discussing the eclipse lines he has made specific allusions to the "enhanced" lines of some of the metals, and to their relationship—or non-relationship—to the eclipse lines.

On p. 347 he says, "These plates give no evidence of any relationship between the bright lines and the 'enhanced' lines, or lines distinctly more intense in the spark than in the arc spectrum, although Sir Norman Lockyer has attached much significance to a supposed connection between them. Some of the enhanced lines are present and some are not, or at least were not conspicuous enough for measurement." In the paragraph immediately following, he says, "In case of titanium, for which Lockyer gives 48 enhanced lines within our limits, we may summarise the comparison as follows: 17 lines do

* Frost, 'Ast.-Phys. Journ.,' vol. 12, p. 307, 1900.

not appear as bright on the eclipse plates; one pair is doubtful, the remainder occur as quite strong lines of the ordinary dark line spectrum, and hence would be expected to appear in the reversing layer, as they do."

If a difference of 0·3 tenth-metre be allowed between the wave-length of an eclipse line and that of the possibly corresponding metallic line (and in some cases Professor Frost accepts a difference of 0·35 or more between his adopted wave-length and Rowland's solar wave-length), the seventeen lines above mentioned dwindle down to ten. That leaves, then, thirty-eight out of forty-eight of the enhanced lines, or about 80 per cent., which agree in position within 0·3 tenth-metre with the eclipse lines. Surely this shows as close a relationship between the enhanced lines of titanium and the eclipse lines, as that between the latter and the stronger of the Fraunhofer lines, for it is stated on p. 345, "of 171 of Rowland's lines, 61 per cent. were measured as bright on the plates."

Nowhere has it been contended that the whole set of enhanced lines belonging to any one metal are represented in the spectrum of any one celestial body; what has been stated is that the enhanced lines of some of the metals are, in general, of paramount importance in the spectra of some stars (*e.g.*, α Cygni), specially prominent in others (*e.g.*, γ Cygni, the spectrum of which, with the exception of the absence of helium lines, very closely resembles that of the chromosphere), and are a marked feature of the spectrum of the chromosphere itself.

Professor Frost either has not noticed, or does not point out, that most of the enhanced lines of titanium, as compared with the ordinary lines of that element, are specially prominent, and are amongst the lines of greatest intensity in his list, as shown in the following table. The first two columns of the table contain respectively the wave-lengths and intensities of Rowland's solar lines (in the region covered by the eclipse lines), which have an intensity of 2 or more, and which have been ascribed to Ti only. Double assignations, of which Ti forms one, have been omitted, as it is difficult, if not impossible, to determine what proportion of the intensity of the solar line is due to each element. The third column indicates whether the titanium line at the given wave-length is an enhanced one or not. The fourth gives the wave-lengths, the fifth and sixth the intensities, and the eighth the origins which Professor Frost has adopted for the corresponding eclipse lines, and the seventh the intensities of the lines reduced from the Kensington eclipse photographs. To make them roughly comparable with Professor Frost's, these intensities have been multiplied by ten throughout, as 1 is adopted for the weakest lines in the Kensington photographs, whereas he adopts 10 for lines just visible.

Solar Lines of Intensity 2 or greater, ascribed by Rowland to Ti only.

Solar – Ti lines λ (Rowland).	Int. in sun.	If enhanced line.	Eclipse.					Remarks.
			Frost.			Kensington.		
			Adopted wave-length.	Intensity. Max. 500. Prism spectra. "Flash" II.	Intensity. Max. 500. Prism spectra. Cusp II.	Int. Max. 100.	Frost's origin.	
4028·50	4	yes	4028·28	35	20	25		Eclipse line undoubtedly due to Ti.
4078·63	3	no	4078·6	15	—	—	Fe, Ti	
4171·21	4	no	4171·30	20	15	—	Ti	
4274·75	2	no	4274·93	75	30	50	Cr	Eclipse line undoubtedly due to Cr.
4285·16	2	no						
4286·17	2	no	4286·0	6				
4288·04	2	no	4287·91	25	25	—	Ti	
4289·24	2	no						
4290·38	2	yes	4290·34	40	20	65	Ti	Line in Kensington photograph probably compounded of Cr 4289·89 and Ti 4290·38
4291·11	3	no }	4291·11	12	12	—	Ti	
4291·28	2	no }						
4294·20	2	yes	4294·41	70	—	50	Fe	Probably due to Fe 4294·30 + Ti 4294·20, but there is more evidence for Ti than Fe.
4298·83	2	no						
4299·80	2	no						
4300·21	3	yes	4300·36	60	20	50	Mn	Evidence in favour of Mn origin very weak, that for Ti very strong.

4300·73	2	no						
4301·16	2	no						
4302·09	2	yes	4301·96	40	15	—	Ti	
4306·08	4	no						
4313·03	3	yes	4312·99	40	25	20	Ti	
4315·14	3	yes	4315·28	40	30	45	Ti, Fe	Eclipse line probably Ti 4315·14 + Fe 4315·26.
4338·08	4	yes	4337·99	25	20	50	Ti, Sr ?	Evidence for Sr negligible.
4341·53	2	yes	—	—	—	—	—	Probably masked by Hγ.
4344·45	2	yes	4344·42	50	25	30	Ti	
4367·84	2	yes	4367·64	25	15	25	Fe	Probably due to Ti 4367·84 + Fe 4367·68, but evidence for Ti much better than that for Fe.
4394·22	2	no						
				Grating spectra.				
				"Flash" I.	"Flash" II			
4395·20	3	yes	4395·27	50	50	70	Ti	
4417·88	3	yes	4417·80	18	30	45	Ti	
4427·27	2	no	4427·4	12	12	30	Ti, Fe	Possibly due to Fe 4427·44 + Ti 4427·27, but evidence for Fe greater than that for Ti.
4443·98	5	yes	4444·0	40	35	70	Ti	
4449·31	2	no						
4450·65	2	yes	4450·6	18	20	50	Ti ?	
4453·49	2	no						
4464·62	2	yes	4464·6	6	12	25	Ti ?	
4468·66	5	yes	4463·8	50	30	60	Ti	
4501·45	5	yes	4501·44	35	35	70	Ti	
4512·91	3	no						
4518·20	3	no	4518·0	—	5			
4522·97	2	no	4522·7	15	25	40	Ti	Eclipse line undoubtedly due, in the main, to enhanced Fe 4522·69.

Solar Lines of Intensity 2 or greater, ascribed by Rowland to Ti only—*continued*.

Solar – Ti lines λ (Rowland).	Int. in sun.	If enhanced line.	Eclipse. Frost. Adopted wave-length.	Eclipse. Frost. Intensity. Max. 500. Prism spectra. "Flash" II.	Eclipse. Frost. Intensity. Max. 500. Prism spectra. Cusp II.	Eclipse. Kensington. Int. Max 100.	Frost's origin.	Remarks.
4527·49	3	no						
4533·42	4	no						
4534·95	4	no						
4535·74	3	no	—	—	—	} 20		λ of eclipse line 4535·9.
4536·09	2	no	—	—	—			
4536·22	2	no						
4544·86	3	no	—	—	—	30		
4548·94	2	no						
4552·63	2	no						
4555·66	3	no						
4563·94	4	yes	4563·94	30	40	75		
4572·16	6	yes	4572·16	45	45	70		
4617·45	3	no						
4623·28	2	no						

In the above list of solar-titanium lines there are thirty-three which are not "enhanced" in the spark spectrum. It will be seen that twenty-three of these—or 70 per cent.—have no corresponding line (within 0·3 tenth-metre) in Professor Frost's record of eclipse lines. Of the nine eclipse lines in the table which do agree approximately in position with unenhanced titanium lines, two are with certainty due to other metals, and in another case there is more evidence for an iron origin than one of titanium. These are indicated in the column for remarks. The remainder are nearly all lines of insignificant intensity.

Of the twenty "enhanced" lines of titanium which occur in the list, nineteen have corresponding lines in Professor Frost's eclipse spectra, the remaining one being also possibly represented, but it falls so near the strong Hγ line that it might be easily masked. Not only are they represented in the eclipse spectra, but in nearly every case the corresponding eclipse line is a prominent one, as will be gathered at once from a glance at the tabular list given.

Professor Frost summarily dismisses the significance of the enhanced lines of titanium in the eclipse spectra, because "most of them occur as quite strong lines in the ordinary dark line spectrum, and hence would be expected to appear in the reversing layer, as they do." But if he would expect one line of a certain solar intensity, he should expect all lines due to the same element which are of an equal solar intensity, to appear in the eclipse spectra. Yet another glance at the foregoing table will show that many of the titanium lines strongly represented in the eclipse spectra are of the lowest intensity in the Fraunhofer spectrum, and that if lines of a certain solar intensity be considered, those that are enhanced lines appear in the eclipse spectra, whereas the unenhanced ones do not.

In this comparison no account has been taken of the relative intensities of the lines in the titanium spectrum itself. Hasselberg has published* a lengthy list of titanium arc lines, and in the region covered by the eclipse spectra records about 250. To compare all these with the eclipse lines would take too much time and space, nor is it necessary. To show the difference in behaviour in the eclipse spectra of the enhanced and the strongest arc lines, two separate lists of titanium lines have been made. The first, which follows immediately, contains all the enhanced lines which occur in Hasselberg's arc list, and the intensities of Professor Frost's and the Kensington eclipse lines which correspond within 0·3 tenth-metre are also given.

* 'Kongl. Svenska Vetenskaps Akad. Handl.,' vol. 28, No. 1, 1895.

Enhanced Lines of Titanium recorded by Hasselberg in Arc Spectrum, and their behaviour in Eclipse Spectra.

Enhanced lines in Hasselberg's Ti arc spectrum.		Eclipse.					Remarks.
			Frost.		Kensington.	Frost's origin.	
		Adopted wave-length.	Intensity max. 500. Prism spectra.		Int. max. 100.		
λ.	Int. Max. 8.		"Flash" II.	Cusp II.			
4025 ·26	2					—	Undoubtedly due to Ti.
4028 ·48	3	4028 ·28	35	20	25		
4053 ·96	3	4053 ·9	12	—	30	Fe, Ti	Probably due to enhanced Ti 4053 ·98 + enhanced V 4053 ·80.
4055 ·18	5	4054 ·98	40	?	—	Fe	Evidence for Ti stronger than that for Fe.
4161 ·67	2	4161 ·81	80	5	35		
4163 ·80	5	4163 ·86	50	12	40	Ti, Cr	Evidence for Cr weak.
4172 ·04	4	4172 ·15	80	15	35	Ti, Fe	
4173 ·66	3	4173 ·75	50	?	45	—	Probably due to enhanced Fe 4173 ·52 + enhanced Ti 4173 ·70.
4174 ·20	2						
4290 ·37	5	4290 ·34	40	20	65	Ti	Line in Kensington photograph probably compounded of Cr 4289 ·89 and Ti 4290 ·38.
4294 ·28	6	4294 ·41	70	—	50	Fe	Probably due to Fe 4294 ·30 + Ti 4294 ·20. More evidence for Ti than Fe.
4300 ·19	6	4300 ·36	60	20	50	Mn	Evidence for Ti origin far outweighs that for Mn.
4302 ·08	5	4301 ·96	40	15	—	Ti	
4313 ·01	6	4312 ·99	40	25	20	Ti	
4315 ·15	4	4315 ·28	40	30	45	Ti Fe	Probably due to Ti 4315 ·14 + Fe 4315 ·26.

4316·96	4	4316·79	12	6			
4321·12	3	4321·06	60	50	50	Sc	Probably due to enhanced Ti 4321·20 + Sc 4320·91.
4330·85	3	4330·71	30	?	25		
4338·05	6	4337·99	25	20	50	Ti, Sr?	Evidence for Sr negligible.
4341·51	3	—	—	—	—	—	Probably masked by Hγ.
4344·47	3	4344·42	50	25	30	Ti	
4350·99	2						
4367·81	3	4367·64	25	15	25	Fe	Probably due to Ti 4367·84 + Fe 4367·68. Better evidence for Ti than Fe.
4374·97	2	4374·8	60	30	70	—	Probably due to enhanced Ti 4374·90 + Sc 4374·63.
4387·00	2						
			"Flash" I	"Flash" II			
4395·17	7	4395·20	50	50	70	Ti	
4395·99	3						
4399·92	5	4399·9	7	—	55	Ti, Cr	
		4400·3	25	30		Sc	
4417·88	5	4417·80	18	30	45	Ti	
4464·60	3	4464·6	6	12	25	Ti?	
4468·65	6	4468·8	50	30	60	Ti	
4488·47	3						
4501·43	6	4501·44	35	35	70	Ti	
4534·15	5	4534·2	40	60	75	Ti, Co	Probably due solely to Ti.
4549·79	6	4549·9	40	55	75	Ti, Co	Probably due to enhanced Fe 4549·64 + enhanced Ti 4549·81.
4563·94	5	4563·94	30	40	75	Ti	
4572·15	6	4572·16	45	45	70	Ti	
4590·11	4	4590·1	12	10	30		

Reference to the above table will show that the "arc" intensities of the enhanced lines vary from 2 to 7 (maximum intensity adopted is 8), and that nearly throughout Frost records corresponding eclipse lines, the majority of the latter being quite prominent.

The second list consists of the very strongest arc lines (intensity 7 and 8) which are not enhanced in the spark spectrum. Here again the intensities of the corresponding eclipse lines, if any, are quoted.

Strongest Arc Lines of Titanium, and their relation to Eclipse Lines.

Titanium arc. (Hasselberg.)		Eclipse.				
		Frost.			Kensington.	Frost's origin.
			Intensity. Max. 500.			
			Prism spectra.			
λ.	Int. Max. 8.	Adopted wave-length.	"Flash" II.	Cusp II.	Int. Max. 100.	
4186·27	7	4186·3	—	5		
4286·15	7	4286·0	6			
4287·55	7	—	—	—	10	
4289·23	7					
4295·91	7	4295·98	7	15		Cr, Ti, Ni.
4298·82	7					
4300·73	7					
4301·23	7					
4306·07	8					
4314·95	7					
4318·83	7	4319·02	20	12		Ca, Mn?
			Grating spectra.			
			"Flash" I.	"Flash" II.		
4427·28	8	4427·4	12	12	30	Ti, Fe.
4457·59	7	4457·8	—	5	—	Ti, V, Zr Mn.
4518·18	7	4518·0	—	5	10	
4533·42	7					
4534·97	7					
4544·83	7	—	—	—	30	
4548·93	7					
4552·62	7					
4617·41	7					

Here, it will be observed, there are only seven out of the twenty strongest titanium arc lines which have possibly corresponding lines in Frost's eclipse spectra. To three of these eclipse lines he assigns no origin; to the others he gives compound origins, three of them involving titanium. In no case is the corresponding eclipse line as

Solar Lines of Intensity 2 or greater, ascribed by Rowland to Fe only. (λ 4500 to λ 4600.)

Solar – Fe lines λ (Rowland).	Int. in sun.	Int. in arc spectrum (K. & R).	If enhanced line.	Eclipse.					Remarks.
					Frost.		Kensington.		
				Adopted wave-length.	Intensity. Max. 500. Grating spectra. "Flash" I.	"Flash" II	Int. Max. 100.	Frost's origin.	
4508·46	4	1	yes	4508·4	7	15	50	Fe ?	
4517·70	3	4	no	4518·0	—	5			
4520·49	3	1	yes	4520·4	8	17	30	Fe ?	
4525·31	5	6	no	4525·0	—	7	—	Fe	
4528·80	8	10	no	4528·6	—	5	30	Fe	Strongest line in this region of the iron spectrum.
4531·33	5	8	no						
4531·80	2	4	no						
4548·02	3	8	no						
4549·64	2	4	yes	4549·9	40	55	75	Ti, Co	Probably due to enhanced Fe 4549·64 + enhanced Ti 4549·81.
4550·94	2	—	no						
4560·27	2	2	no						
4574·90	2	4	no						
4584·02	4	2	yes	—	25	35	70	Fe	
4587·31	2	4	no						
4592·84	4	8	no						
4595·54	2	4	no						
4596·25	2	2	no						
4598·30	3	6	no						

strong as the majority of those which are the representatives of the enhanced lines.

In the case of iron, all the well-enhanced lines are represented in the eclipse spectra, but they are not of quite the same prominence as the titanium enhanced lines. They are, so far as their intrinsic intensities in the iron arc spectrum are concerned, quite insignificant lines as compared with the majority of other iron lines, but their importance lies in the fact that they are a class of lines of special behaviour, being relatively stronger in the spark spectrum than in the arc. In the eclipse spectra they are undoubtedly represented by stronger lines than are the *great majority* of unenhanced iron lines, however strong the latter may be in the iron arc spectrum itself.

Owing to the great number of iron lines in the solar spectrum, a comparison similar to that given for titanium over the whole region covered by the eclipse lines would necessitate the compilation of a very lengthy list. But whatever evidence there is either one way or another should be revealed by a comparison over a limited region, so it is proposed to take that between λ 4500 and λ 4600, since the proportion of enhanced to unenhanced iron lines is there greatest, and therefore a better opportunity is afforded of a fair comparison of the behaviour of the two classes of lines. The table given on p. 187 is arranged in exactly the same way as in the case of titanium, with the exception that there is an additional column showing the intensities in the arc spectrum, as recorded by Kayser and Runge.

It will be seen that the unenhanced lines are here also unrepresented in the eclipse spectra, with the possible exception of three, which are recorded as very weak lines in one of Professor Frost's spectra, but are missing from the other. All the enhanced lines, however, although they have the weakest arc intensities, appear in each of the eclipse spectra, and have abnormal intensities compared with those corresponding to the unenhanced lines. It must be pointed out that only four of the nine enhanced iron lines in the part of the spectrum considered appear in the above list, because they are the only ones which are given in Rowland's origins for solar lines. At least four out of the remaining five—those at $\lambda\lambda$ 4515·51, 4522·69, 4556·10, 4576·51, probably correspond to the solar lines 4515·51, 4522·69 (or possibly 4522·80), 4556·06, and 4576·51, to which Rowland has assigned no origin. The outstanding line at λ 4541·40 is doubtfully present in the solar spectrum. The first three of these five have corresponding lines in the eclipse record; the other two have not. In the Kensington reductions of eclipse spectra there are, however, lines agreeing (within 0·3 tenth-metre) with every one of the enhanced lines mentioned.

"Further Observations on Nova Persei, No. 2." By Sir NORMAN LOCKYER, K.C.B., F.R.S. Received and Read March 28, 1901.

In continuation of two previous papers, I now bring the observations of the Nova made at Kensington to midnight of March 25. Since the last paper* of March 7th, estimates of the magnitude of the Nova have been made on ten evenings, visual observations of the spectrum on eight evenings, and photographs of the spectrum on four evenings up to the evening of the 25th.

In consequence of the greater faintness of the Nova, the 6-inch prismatic camera has not been utilised, but the 10-inch refractor to which it is attached has been used for eye observations of the spectrum with a McClean spectroscope.

With the 30-inch reflector four photographs have been secured on the evenings of the 6th, 10th, 24th, and 25th by Dr. Lockyer, and with the 9-inch prismatic reflector seven photographs on the nights of 10th, 21st, and 25th by Messrs. Butler and Hodgson.

Change of Brightness.

Since March 5th the magnitude of the star has been gradually decreasing, but between the nights of the 24th and 25th the light of

* *Supra*, p. 142.

the Nova decreased very suddenly, dropping from 4·2 to 5·5 in twenty-four hours, and becoming only just visible as a naked-eye star.

The following gives a summary of the eye estimates made by (1) Dr. Lockyer, (2) Mr. Fowler, and (3) Mr. Butler:—

	(1.)	(2.)	(3.)
March 5......	2·7	2·7	—
6......	2·9	—	—
9......	—	3·5	3·5
10......	3·7	—	—
11......	—	—	<4·0
12......	—	3·8	—
21......	—	4·0	4·2
22......	—	—	—
23......	4·2	4·2	4·5
24......	4·2	4·2	4·5
25......	5·5	5·5	5·5

Colour.

The colour of the Nova has undergone some distinct changes since the observation on March 5th last, when it was shining with a clarety-red hue. On the 9th and 10th it was observed to be much redder, due probably to the great development of the red C line of hydrogen.

On the 23rd and 24th, the star was noted as yellowish-red, while on the 25th (after the sudden drop in magnitude) it was very red, with, perhaps, a yellow tinge.

The Visual Spectrum.

Since March 5th the spectrum from C to F has become very much fainter, the bright lines of hydrogen being relatively more prominent than they were before; indeed, C and F throughout this period have been the most conspicuous lines, especially the former, while the bright lines λλ 5169, 5018, and 4924, and the line in the yellow near D, were the most prominent of the others.

All these lines have been gradually becoming weaker, but there is an indication that λ 5018* has been brightening relatively to λ 5169.

Accompanying the great diminution in the light of the Nova observed on the evening of the 25th, the spectrum was found to have undergone a great change: the continuous spectrum had practically disappeared, and a line near D (probably helium, D_3) became more distinct. The other lines were hardly visible.

* The line near this wave-length in later observations is probably the chief nebular line 5007, which accounts for the apparent brightening of 5018.

The Photographic Spectrum.

On March 6th the photographs were very similar to those obtained in the earlier stages, the only apparent difference being in the relative intensity of the bright hydrogen lines as opposed to those having other origins, most of which have been shown to be probably due to iron and calcium. The hydrogen lines have sensibly brightened, while the others have become much feebler.

The photograph of March 10th shows a further dimming of the bright lines other than those of hydrogen.

On March 25th, when the next good photograph was taken, the spectrum had undergone great modifications. The hydrogen lines are still very bright, though they do not show the structure which they did in the photographs taken between February 25th and March 10th. The bright lines other than those of hydrogen, which are seen in the earlier photographs, have now disappeared, and other lines become visible. The continuous spectrum has also greatly diminished.

Approximate determinations of the wave-length of these new lines have been made by Mr. Baxandall by comparison with lines of known wave-length in the spectra of α and ϵ Persei photographed with the same instrument. They are as follows :—

λ

3870. Broad, and merging into $H\zeta$ (3889).
4367. Weak.
4472. Not very strong. Probably helium (λ 4471·6).
4565. Weak.
4650. Very strong broad line. Possibly the 465 line of the bright-line stars and the belt stars of Orion.
4690. Moderately strong. Possibly new hydrogen (λ 4687·88) seen in bright-line stars and some Orion stars.
471. Weak. Probably helium (λ 4713).

The hydrogen lines in the spectra are $H\zeta$, $H\epsilon$, $H\delta$, $H\gamma$, and $H\beta$.

The lines at λ 3870 and 4650 are perhaps identical with those observed by von Gothard* in the spectrum of Nova Aurigæ after it had become nebular, but associated with these lines in his record is the chief nebular line at 5007, no trace of which is yet visible in the photographs of the spectrum of Nova Persei. On the other hand, $H\beta$, which is the brightest line in the present spectrum of Nova Persei, does not appear at all in von Gothard's spectrum of Nova Aurigæ.

Characteristics of the Hydrogen Lines.

In my former paper I referred to the structure of the broad bright lines of hydrogen. A more detailed examination of the lines as photo-

* 'Ast.-Phys. Jour.,' vol. 12, 1898, p. 51.

graphed on several evenings shows that this structure has been undergoing changes.

The annexed figure (fig. 1) gives light curves showing the variation

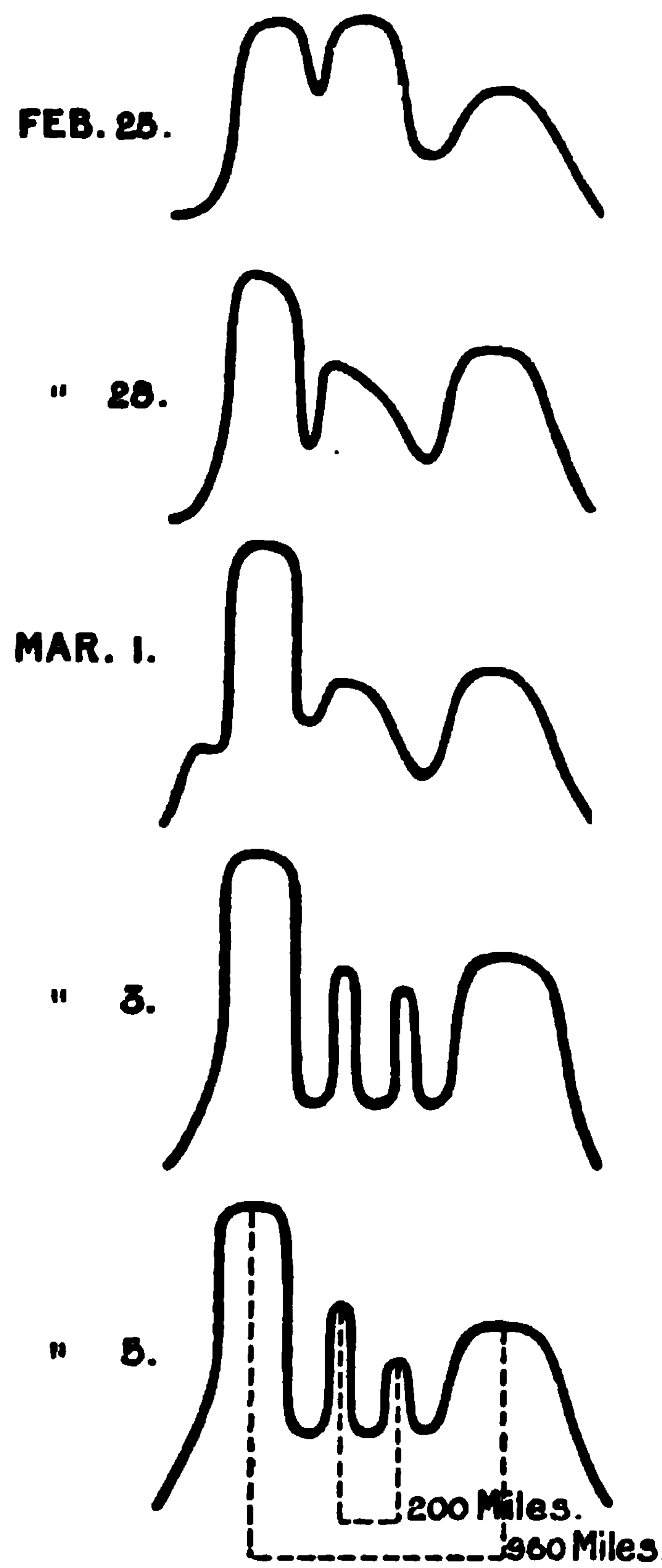

FIG. 1.—Light curve of Hβ (6-inch objective prism).

in the loci of intensity of the line Hβ, as photographed with the 6-inch prismatic camera. These curves were plotted by Messrs. Baxandall and Shaw independently of each other, and I have satisfied myself of their accuracy. It will be seen that on February 25th there were three points of maximum luminosity, the two maxima on the blue side being of equal intensity, and greater than the third on the red side. By March 1 the centre one had been greatly reduced in intensity, and on the 3rd it had been broken up into two portions, thus making four distinct maxima.

Rough measures made on the relative positions of these points of maxima show that the difference of velocity indicated between the two external maxima is nearly 1,000 miles per second, while that between

the two inner maxima is 200 per second. We thus have indications of possible rotations or spiral movements of two distinct sets of particles travelling with velocities of 500 and 100 miles per second.

A similar examination of the F and G lines of hydrogen in the photographs obtained with the 30-inch reflector has also been made by Dr. Lockyer, and the light curves for the G line are here illustrated (fig. 2). In this longer series the most important point comes out that

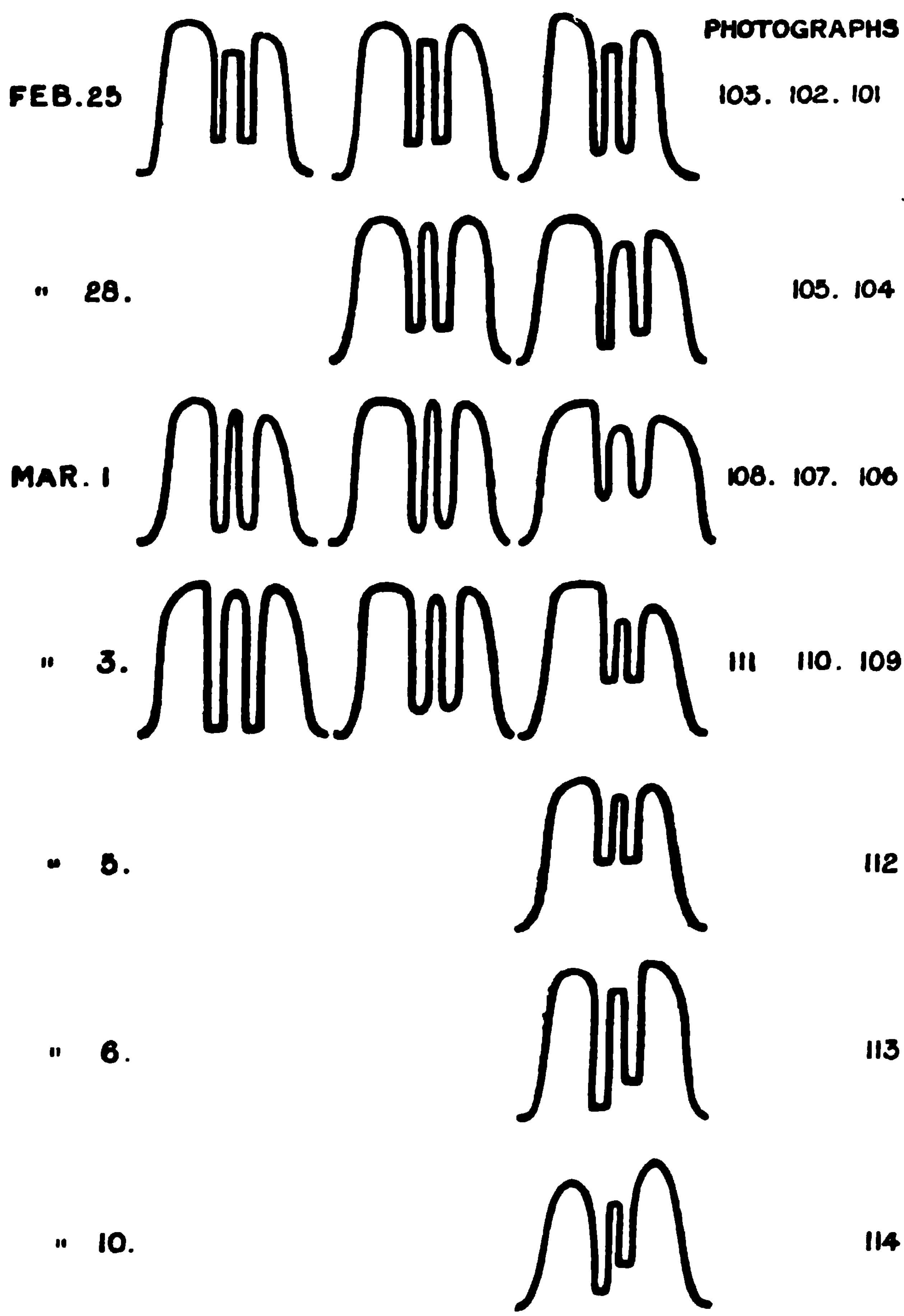

FIG. 2.—Light curve of Hγ (30-inch reflector).

the maximum intensity changes from the more to the less refrangible side of the bright hydrogen line.

The small dispersion given by the 30-inch prevents some of the details recorded by Messrs. Baxandall and Shaw from being seen.

So far as the observations have gone, they strongly support, in my

opinion, the view I put forward in 1877 that "new stars" are produced by the clash of meteor-swarms; and they have suggested some further tests of its validity.

We may hope since observations were made at Harvard and Potsdam very near the epoch of maximum brilliancy, that a subsequent complete discussion of the results obtained will very largely increase our knowledge. The interesting question arises whether we may not regard the changes in spectrum as indicating that the very violent intrusion of the denser swarm has been followed by its dissipation, and that its passage has produced movements in the sparser swarm which may eventuate in a subsequent condensation.

My best thanks are due to those I have named for assistance in this inquiry.

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MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

APPENDIX TO VOL. LXI.

[*From Proceedings of the Royal Society, Vol. LXVIII.*]

With indication of the original pagination.

No. 3.

CONTENTS.

"The Solar Activity 1833–1900." By WILLIAM J. S. LOCKYER, M.A., Ph.D., F.R.A.S., Assistant Director, Solar Physics Observatory, Kensington. Communicated by Sir NORMAN LOCKYER, K.C.B., F.R.S. Received April 29,—Read May 23, 1901.

Introduction.

A close examination of the curves representing the varying amount of spotted area on the Sun's surface, shows that no two successive cycles are alike either in form or area. The individuality of the cycles seems, on further inspection, to be repeated after a certain period of time, and this peculiarity, coupled with a like variation in the curves representing the variations of the magnetic elements, and with suspected cycles of change in various terrestrial phenomena, suggested a new investigation of the whole subject.

The object of this communication is to place before the Royal Society the first results which an examination of the various records has furnished.

Dr. Rudolf Wolf,* of Zürich, from a study of the sunspot observations made up to the end of 1875, drew attention to the facts, to use

* 'Mem. R. Astron. Soc.,' vol. 43, p. 200.

his own words, that "la fréquence des taches solaires persiste à changer périodiquement depuis leur découverte en 1610; que la longueur moyenne de la période est de $11\frac{1}{9}$ ans, et que cette même période satisfait aux changements de la variation magnétique, et même de la réquence des aurores boréales."

Dr. Wolf was careful to point out that it was only the *mean length* of the solar period that covered a period of $11\frac{1}{9}$ years, and that the real length of any one period might differ from this value by as much as two years. The form in which he stated this result* was

$$T = 11{\cdot}111 \pm 2{,}030 \text{ (als Schwankung)} \pm 0{,}307 \text{ (als Unsicherheit)};$$

where T represented the length of the period, ± 2,030 the variation from the mean value, and ± 0,307 the probable error of the determination.

His attention was also drawn to the fact that the times of maxima did not occur a constant number of years after a preceding minimum, and he was led to determine the *mean* time of occurrence of the maximum after the preceding minimum and of the minimum after the preceding maximum, giving the *mean* intervals as 4·5 and 6·5 years respectively.

Further, he at first concluded that the total spotted area for each period was nearly constant, but, as he later remarks,† this view could not be held, as these quantities not only varied but indicated "eine bestimmte Gesetz-mässigkeit." The length of the period of this variation he gave as about 178 years, which covered practically sixteen ordinary sunspot periods. ("11,1111 × 16 = 177,7777.")

Somewhat later Dr. Wolf was led to suggest a shorter period of 55·5 years, which comprises about five ordinary eleven-year periods.

In a recent paper‡ Professor Simon Newcomb has published the results of his investigation of the irregularities in the successive sunspot periods, using as a basis Dr. Wolf's numbers up to the end of 1872, and the spot areas as derived from the Greenwich reduction of the solar photographs taken daily at Greenwich, Dehra Dun, and Mauritius.

The final conclusion at which he arrives is summed up in the following paragraph :—

"Underlying the periodic variations of spot-activity there is a uniform cycle unchanging from time to time and determining the general mean of the activity."

Professor Newcomb mentions, however, no length of period for this cycle, but speaking of its origin he remarks, "whether the cause of this cycle is to be sought in something external to the Sun or within

* 'Astron. Mittheil.,' Wolf, 187 ; p. 40.

† 'Astron. Mittheil.,' 1876, p. 47 *et seq.*

‡ 'The Astro-Physical Journal,' vol. 13, No. 1, 1901, p. 1.

it; whether, in fact, it is in the nature of a cycle of variations within the Sun, we have, at present, no way of deciding."

In the investigations on periods of solar activity most workers have relied simply on Wolf's numbers, which are given by him back to the year 1749. Any one acquainted with these knows that from the time *systematic* observations of the Sun's surface were commenced by Hofrath Schwabe (1833), these numbers agree very closely with the actual facts; but before that date, the numbers are based, not on facts alone (which were not very numerous), but on a system of "meaning,"* suggested by the results of the observations from 1833 to 1876.

Although then Dr. Wolf was able to present us with a curve dealing with the spotted area from 1749, it was decided for the present communication to limit the discussion to those relative numbers which are based on the actual systematic observations since 1833. This necessarily restricted the investigation to a comparatively short number of years, namely, sixty-six (1833–1899), but it was thought that any variations detected, if greater than any which might be justifiably considered errors of observation, would be based on sound facts, and not on uncertain data.

The important magnetic results obtained from a discussion of the Greenwich Observations by Mr. William Ellis,† placed at my disposal a most valuable check on any variation that might be obtained from the sunspot curves, Mr. Ellis having shown that the curves for the magnetic elements are in almost exact accord with those of the sunspots obtained by Dr. Wolf. In this connection Mr. Ellis writes‡:

"Considering that the irregularities in the length of the sunspot period so entirely synchronise with similar irregularities in the magnetic period, and also that the elevation or depression of the maximum points of the sunspot curve is accompanied by similar elevations and depressions in the two magnetic curves, it would seem, in the face of such evidence, that the supposition that such agreement is probably only accidental coincidence can scarcely be maintained, and there would appear to be no escape from the conclusion that such close correspondence, both in period and activity, indicates a more or less direct relation between the two phenomena, or otherwise the existence of some common cause producing both. The sharp rise from minimum epoch to maximum epoch, and the more gradual fall from maximum epoch to minimum epoch, may be pointed out as characteristic of all three curves."

* For Wolf's method of "meaning" see 'Astronomische Mittheilungen,' von Rudolf Wolf, Zürich, 1876, p. 39 *et seq.*

† 'Roy. Soc. Proc.,' vol. 63, p. 64.

‡ *Ibid.*, p. 70.

The Sunspot and Magnetic Epochs employed.

As this paper deals mainly with the times of minima and maxima of both the sunspot and magnetic curves, it was necessary to utilise the results obtained from curves which had been "smoothed," as the original curves are of a subsidiary oscillatory character, especially at maximum.

The sunspot curves just referred to are reproduced in fig. 1. They are so arranged in order of date that each individual curve can be examined separately. The times of succeeding *minima* are arranged vertically under each other, so that any variation as regards acceleration or retardation of the following maxima, and any inequality in the length of the period minimum to minimum can be seen at a glance.

Up to the sunspot maximum of 1870·6 Dr. Wolf has published* the dates of these epochs, and these are utilised here. The more recent epochs have been brought together by Mr. Ellis,† and these complete the data available up to the last epoch, namely, the maximum of 1894·0.

Each of these epochs is indicated in fig. 1 by a short arrow with the corresponding dates. The magnetic epochs here used are those published by Mr. Ellis in the paper just mentioned, and obtained from curves smoothed similarly to those of the sunspot curves. Unfortunately the observations he discussed only commenced in the beginning of 1841, so that comparisons cannot be made previously to this date.

The smoothed curves obtained by Mr. Ellis are not here reproduced, but they will be found in his valuable paper‡ published in 1880.

The Sunspot Curves. Minimum to Maximum.

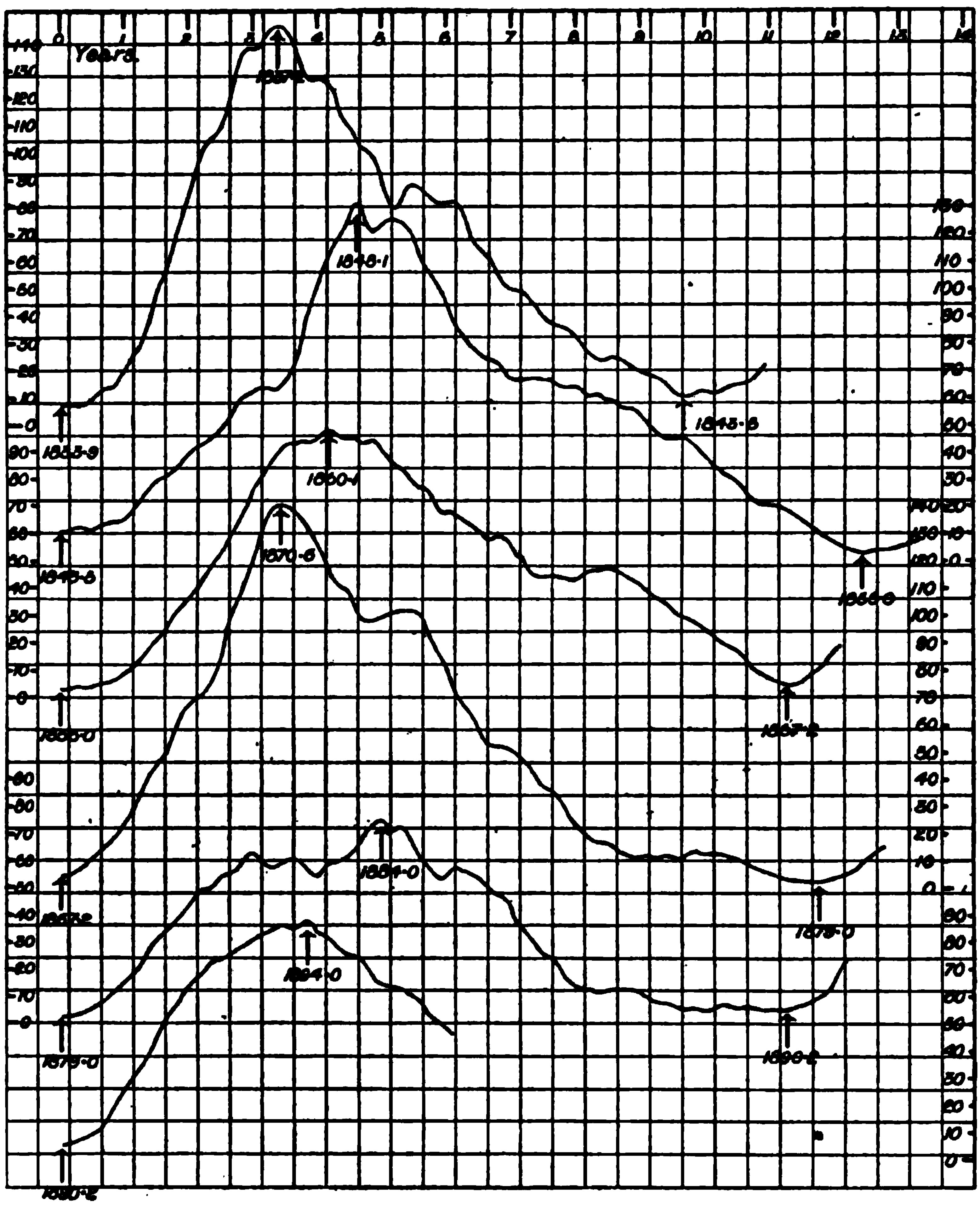
In the following table are brought together the dates of the epochs of maxima and minima :—

Sunspot epochs (Wolf).		Maximum *minus* minimum years.
Minimum.	Maximum.	
(1) 1833·9	1837·2	3·3
(2) 1843·5	1848·1	4·6
(3) 1856·0	1860·1	4·1
(4) 1867·2	1870·6	3·4
(5) 1879·0	1884·0	5·0
(6) 1890·2	1894·0	3·8
		Mean 4·03

* 'Mem. R. Astron. Soc.,' vol. 43, p 202.
† 'Roy. Soc. Proc.,' vol. 63, p. 67.
‡ 'Phil. Trans.,' 1880, Part II, Plate 22.

If these figures in the last column be utilised as ordinates and the time element as abscissæ, the curve in fig. 2 (curve B) is produced. The peculiarity of this curve is that we have a very rapid rise to a maximum in 1843, and slow fall to the minimum in 1867. This is followed

FIG. 1.

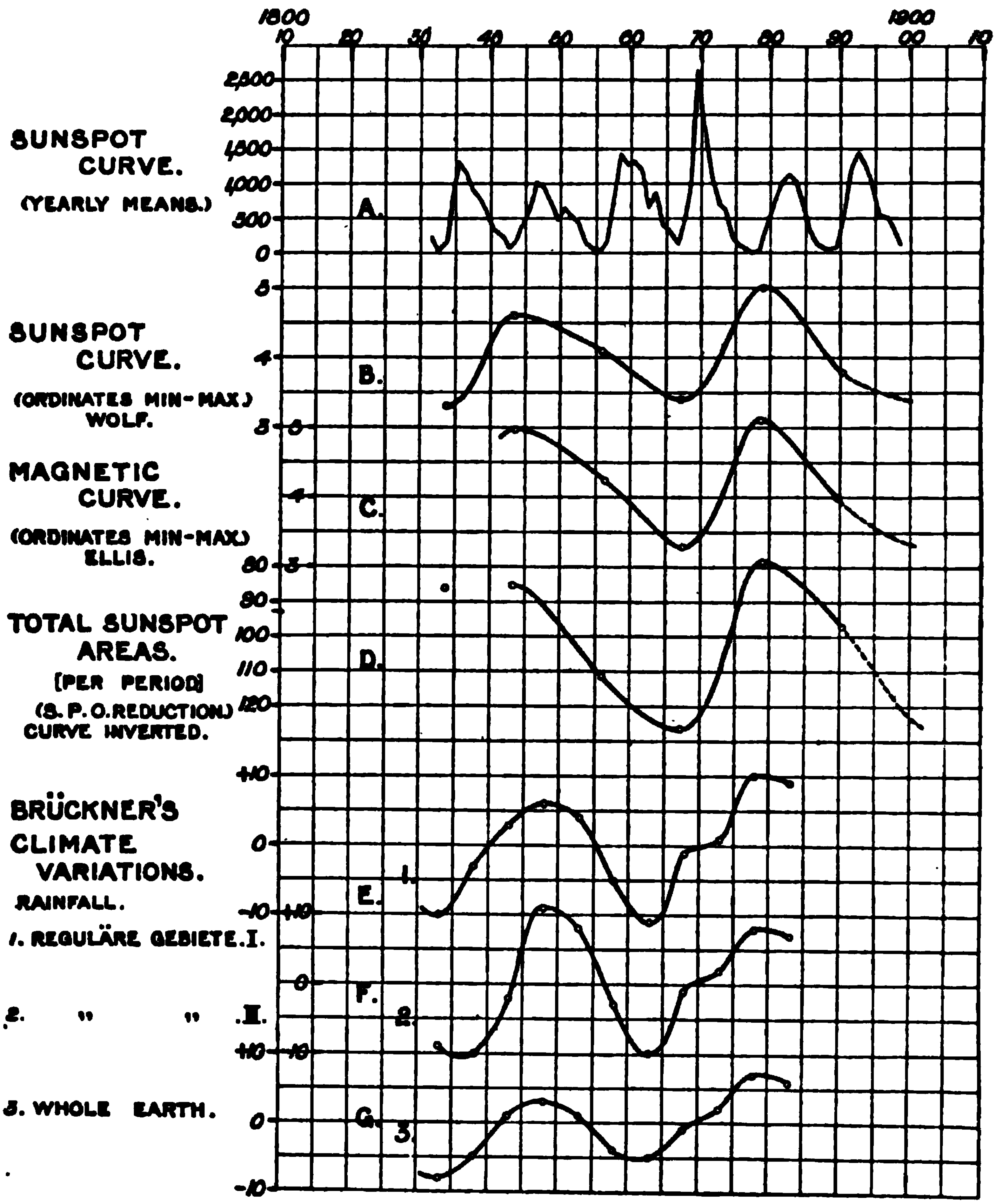


by a similar rapid rise to the next maximum in 1879 and a gradual fall as far as observations at present indicate.

The curve thus indicates that there is some law at work which introduces a secular variation by retarding the sunspot maxima in relation to the preceding minima.

The period of this retardation can be deduced by taking the interval between the times of maxima or minima of this secular variation curve. By considering the minima, *i.e.*, from 1833·9 to 1867·2, we have a period of 33·3 years, and if we take the maxima

Fig. 2.



at 1843·5 and 1879·0 we obtain 35·5 years. The mean of these two values gives a period of 34·4 years.

The Magnetic Curves. Minimum to Maximum.

Mr. Ellis's values for the dates of the magnetic epochs were investigated in exactly the same way as the sunspot epochs were examined.

It may be again mentioned that as the observations he reduced only begin in the year 1841, no comparison can be made with the epochs of 1833·9 and 1837·2.

Forming the table of maximum *minus* minimum as before and adding in the last column the values of maximum *minus* minimum of the sunspot curves from the previous table for the sake of comparison, we have as follows:—

Magnetic epochs (Ellis).		Maximum *minus* minimum.	
Minimum.	Maximum.	Magnetic.	Sunspots.
(1) —	—	—	3·3
(2) 1843·60	1848·55	4·95	4·6
(3) 1856·15	1860·40	4·25	4·1
(4) 1867·55	1870·85	3·30	3·4
(5) 1878·85	1883·90	5·05	5·0
(6) 1889·75	1893·75	4·00	3·8

The nearly complete parallelism of the numbers in the last two columns indicates their strict accord with each other.

The curve showing this magnetic variation is given in fig. 2 (curve C), and it is practically a counterpart of curve B.

The value for the length of the period, as gathered from the interval between the two maxima of this curve at 1843·60 and 1878·85, is 35·25 years, which does not differ very much from the value deduced from the maxima of the corresponding sunspot curve, namely, 35·5 years.

Sunspot and Magnetic Curves Combined. Minimum to Maximum.

By combining the values of the intervals (minimum to maximum) from both the sunspot and magnetic curves, their mean values can be determined as shown in the last column of the following table, the general mean for the whole period being added below:—

From minimum occurring about	Mean of sunspot and magnetic intervals in years.
(1) 1833	3·3
(2) 1843	4·77
(3) 1856	4·17
(4) 1867	3·35
(5) 1879	5·25
(6) 1890	3·90
	Mean .. 4·12

Since these numbers cover more than a complete cycle, they may be combined so that mean values for the intervals minimum—maximum may be obtained for those epochs when the intervals have their largest, intermediate, and smallest values. Thus in the years 1843 and 1879 the maxima followed the minima in 4·77 and 5·25 years respectively, the mean interval thus being 4·91 years. For the intermediate stage (combining (3) and (6)) a value of 4·03 years is found, while for the minimum interval combining (1) and (4) this value 3·32 years.

The actual epoch of maximum relative to the preceding minimum oscillates about the mean value, its greatest amplitude being in the mean 0·8 *year.*

The Total Sunspot Areas. Minimum to Minimum.

The great divergence in the amount of spotted area during consecutive eleven-year cycles suggested that perhaps this periodical retardation of the maxima with respect to the each preceding minimum might be accompanied by variations following the same law. It was observed that when a maximum occurred comparatively soon after a minimum, the tendency of the whole spotted area for that sunspot period was to be increased.

I have been permitted for this inquiry to utilise the values which have quite recently been obtained at the Solar Physics Observatory from a new reduction of the curve representing the solar spotted area, and these values, representing the total spotted area in millionths of the Sun's visible hemisphere from minimum to minimum, are given in the last column of the following table :—

Sunspot period from		Total spotted area.
From minimum	to minimum.	
1833·9	1843·5	86 003
1843·5	1856·0	85 201
1856·0	1867·2	111 514
1867·2	1879·0	126 188
1879·0	1890·2	78 353
1890·2	1901· +	96 734 +

The figures in the last column show a similar but inverted sequence to those in the previous tables. Thus from minimum 1867·2 to the following maximum 1870·6 we have a short interval of time; the spotted area for that period is greatest. If the above values in the last column be graphically shown, and the curve inverted, we have a remarkable similarity (fig. 2, Curve D) to the two curves B and C

previously described. Special attention is called to the slow fall from 1843 to the minimum at 1867·2, and the rapid rise to 1879·0.

It may be remarked that the value for the total spotted area for the period 1833·9 to 1843·5, the earliest value in point of time dealt with, is not quite in harmony with the other values. It is probable that although at this period the time of maximum and minimum could be accurately determined, the values may be too small owing to the fact that Schwabe's observations were not made at that period quite on a uniform plan. Mr. Warren de la Rue and Professor Balfour Stewart* on this point wrote :—

"By the commencement of 1832 Schwabe had matured his system to such an extent as to give, no doubt with considerable precision, the shape and area of each group; although it was not until the commencement of 1840 that he finally fixed upon the system of delineation, which he henceforth pursued up to the time when he discontinued his observations."

The above suggestion seems to be borne out by the reduction of sunspot photographs secured at the Wilna Observatory, where it was found that the maximum of 1870 was of about the same order as that of 1836. The Report of the Wilna Observatory for the year 1871 refers to this point in the following terms† :—

"The curve traced from our observations about the last maximum period of spots (1870) is one and a-half times as high as that of the three most recent periods, *i.e.*, the total sum of the areas of the spots about the maximum period of 1870 was one and a-half times larger than during the last thirty-six years. This marked difference obliged us to enter upon a double verification of our calculations, but we did not discover any appreciable errors."

With reference to the value given in the last line of the last column of the table, although this is probably very near the truth, it is yet impossible to state the date of the present minimum (1901·2 probably). All the areas recorded since the minimum of 1890 and up to the beginning of 1900 have been employed; this value is, however, only slightly below the real one, so that a + sign has been printed against it.

If, therefore, these two facts be kept in mind, it will be seen that the inverted total sunspot-area curve can be considered practically an exact counterpart of the other two curves.

The Total Area of the Magnetic Curves. From Minimum to Minimum.

The remarkable similarity between the magnetic and sunspot curves, especially in the later years when such observations are naturally more

* 'Report of the Committee on Solar Physics, 1882.' Appendix B, p. 77.

† *Ibid.*, Appendix D, p. 154.

accurate, made it unnecessary to discuss the variation (as shown in the case of the sunspot areas) regarding the total areas of the curves from minimum to minimum. This variation seems to be more pronounced in the curve representing the horizontal force than in that representing declination.

Length of the Period of Variation thus determined.

In summing up the values obtained for the length of the secular period of variation under discussion, we form the following table :—

	Maximum to maximum. Years.	Minimum to minimum. Years.
Sunspot curve	35·5	33·3
Magnetic „	35·25	—
Total spotted area for period	35·5	—
Means	35·41	33·3
Combined mean	34·89	

The observations thus lead to the conclusion that *underlying the ordinary sunspot period of about eleven years there is another cycle of greater length, namely, about thirty-five years.*

This cycle not only alters the time of occurrence of the maxima in relation to the preceding minima, but causes changes in the total spotted area of the sun from one eleven-year period to another.

The Variation in the Length of the Interval Minimum to Minimum.

Having found a definite variation in the length of the interval minimum to maximum, the curves show a further variation when the interval—minimum to minimum—was considered. An attempt was therefore made to see if any law could be traced, but the inquiry only led to a negative result.

The following table contains the values for the periods—minimum to minimum—and the differences from the mean, for both the sunspot and magnetic curves individually and combined. It will be seen that the alternation of signs in the columns showing the sunspot differences is not corroborated by the magnetic differences, but when the combined values are used this oscillation for consecutive periods is still *en evidence* :—

Minimum beginning in the year	Sunspots.		Magnetics.		Combination.	
	Minimum to minimum.	Differences from mean.	Minimum to minimum.	Differences from mean.	Minimum to minimum.	Differences from mean.
	Years.	Years.	Years.	Years.	Years.	Years.
1833–1843	9·6	−1·7	..	..	9·6	−1·7
1843–1856	12·5	+1·2	12·55	+1·0	12·52	+1·32
1856–1867	11·2	−0·1	11·40	−0·14	11·30	+0·10
1867–1879	11·8	+0·5	11·30	−0·24	11·55	+0·35
1879–1890	11·2	−0·1	10·90	−0·64	11·05	−0·15
Means..	11·3	—	11·54	—	11·20	—

Although there is a suspected variation in the length of both the magnetic and sunspot periods (reckoning from minimum to minimum), which increases and decreases in *alternate* eleven-year periods from a mean value, the observations do not extend over a sufficient interval of time to allow a more definite conclusion to be drawn.

Relation of the Sunspot Curve to the Light Curve of η Aquilæ.

It is generally conceded that the spots on the surface of the Sun are the result of greater activity in the circulation in the solar atmosphere, and therefore indicate greater heat and, therefore, light. This being so, the curve representing the spotted area may be regarded as a light curve of the Sun.

The Sun may thus be considered a variable star (1) the light of which (reckoning from minimum to minimum) is variable, with a mean value of about 11·1 years; (2) the epoch of maximum does not occur a constant number of years after the preceding minimum, but varies regularly, the cycle of variations covering about 35 years.

It is interesting therefore to inquire whether there be any other known star or stars which exhibit variations similar in kind to those given above.

In the year 1896 I undertook the investigation of all the observations, whether published or not, of the variable star η Aquilæ * which had been made between the years 1840 to 1894, numbering in all 12,000.

For the present inquiry the light curve of this star is of great interest, as its chief peculiarities are similar to those I have indicated in connection with the sunspot curve.

Not only are the more rapid rise to maximum and slow fall to

* 'Resultate aus den Beobachtungen des veränderlichen Sternes η Aquilæ,' Inaugural-Dissertation, Universit. Göttingen, 1897 (Dulau and Co., London).

minimum distinct features of the curve, but the periods (reckoning from minimum) vary slightly in length in the course of many *mean* periods. More important still, the time of occurrence of the maximum in relation to the preceding minimum varies to a comparatively *large* extent in the course of *few* mean periods. The facts arranged in tabular form sum up the information with regard both to the sunspot curve and that of η Aquilæ.

To facilitate the comparison, the different intervals of time converted into fractions and multiples of the sunspot (Q) and η Aquilæ (P) periods are given in separate columns.

		Light curve of			
		Sun.		η Aquilæ.	
Minimum to minimum.	Mean value	Years. 11·20	= Q	$7^d\ 4^h\ 14^m\ 4$	= P
	Period of variation	Unknown	?	—	2400 P
	Maximum variation from mean	± >1·4	± >0·12 Q	$\pm 8^h$	0·017 P
Minimum to maximum.	Mean value	4·12 (about)	0·37 Q	$2^d\ 5$	0·31 P
	Period of variation	34·8 "	3·10 Q	—	400 P
	Maximum variation from mean	±0·8 "	±0·07 Q	$\pm 5^h$	±0·03 P

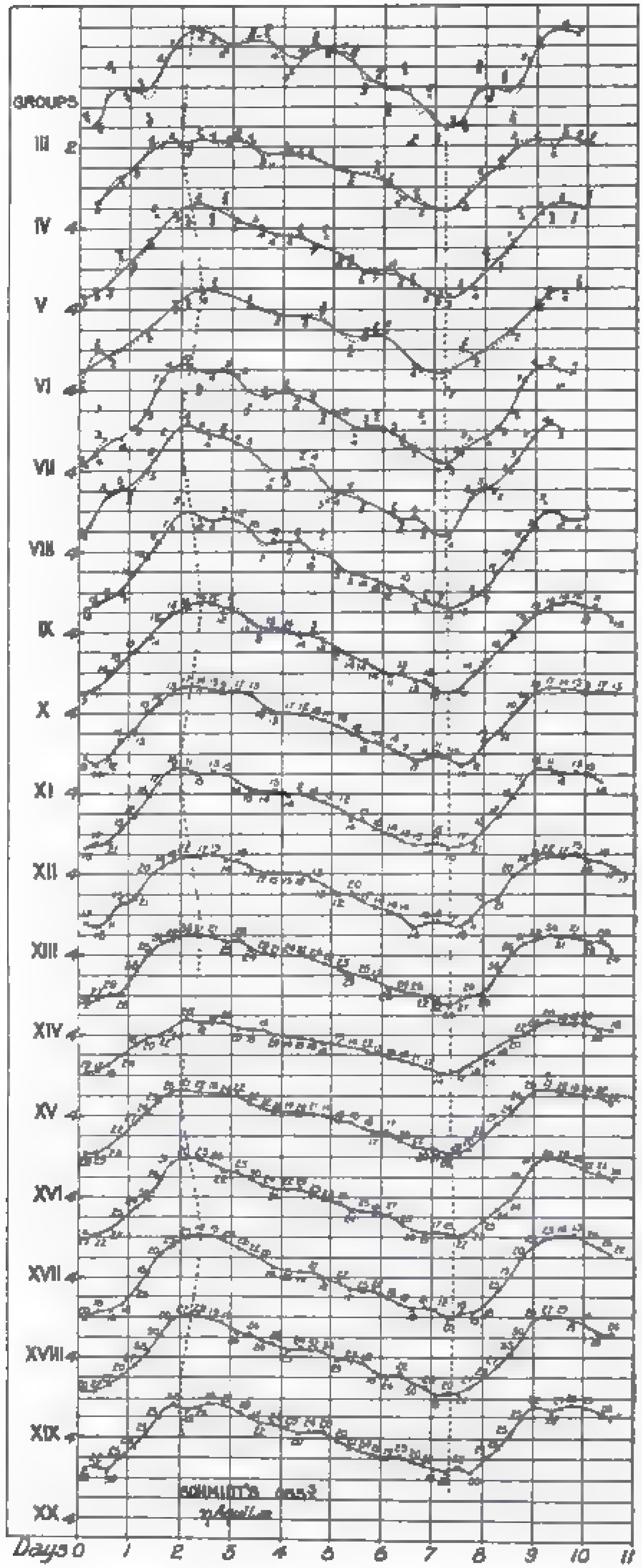
Fig. 3 is a reproduction of a set of light curves of the star η Aquilæ, in which the dotted line and the two vertical wavy and oblique dotted lines passing through the points of maxima and minima indicate the variations of the times of maxima and minima.

The curve for each group is the result of a combination of the observations made over a period equal in length to 100 mean periods (mean period = $172^h{\cdot}2344$) of the star. This whole set of curves is the result of a discussion which I made of all the observations of η Aquilæ made by one observer, Herr Julius Schmidt.

Other Cycles of about Thirty-five Years.

Having found that, in addition to the well-known eleven-year period of sunspot frequency, there is another cycle which extends over about thirty-five years, and which is indicated clearly, as has been shown, both by the changes in the times of the occurrence of the epochs of maxima and in the variations in area included in consecutive eleven-year periods of both sunspot and magnetic curves, it is only natural to suppose that this long-period variation is the effect of a cycle of disturbances in the Sun's atmosphere itself.

Fig. 3.


GROUPS
III
IV
V
VI
VII
VIII
IX
X
XI
XII
XIII
XIV
XV
XVI
XVII
XVIII
XIX
XX
Days 0 1 2 3 4 5 6 7 8 9 10 11

Such a cycle, if of sufficient intensity, should cause a variation from the normal circulation of the Earth's atmosphere, and should be indicated in all meteorological and like phenomena.

It is not intended to go into any detail as regards such terrestrial variations, but it may be noted that much important work has been done on the investigation of changes in climates by Professor Eduard Brückner,* who expended immense labour during many years in the promotion of the inquiry. Professor Brückner did not restrict his discussion to observations made over a small area or for a short interval of time, but utilised those made in nearly every part of the civilised world, and extending as far back in point of time as possible. Further, he did not restrict himself to the discussion of the observations of one or two meteorological phenomena, but examined critically all likely sources from which such changes as he expected could be detected. Thus he sought variations in the observations of the height of the waters in inland seas, lakes, and rivers; in the observations of rainfall, pressure, and temperature; in the movements of glaciers; in the frequency of cold winters; growth of vines, &c.

The result of the whole of the investigation led him to the conclusion that there is a *periodical variation in the climates over the whole earth, the mean length of this period being* 34·8 ± 0·7 *years.*

It may be of interest to remark, that so convinced was Professor Brückner of the undoubted climate variations that he deduced, and so certain was he that such variations could only be caused by an external influence, that he investigated Wolf's sunspot numbers to see whether such a cycle was indicated.

Misled by the long period of variation of sunspots of fifty-five years as suggested by Wolf, he was led to conclude that his climate variation was independent of the frequency of sunspots. He sums up his conclusion in the following words† :—

"Die Klimaschwankungen vollziehen sich unabhängig von den Schwankungen der Sonnenflecken-Häufigkeit; eine 55-jährige Periode der Witterung, wie sie der letzteren entsprechen würde, ist in unseren Zusammenstellungen nicht zu erkennen."

Nevertheless, he was led to make the bold suggestion, that such a variation as he sought must really exist in the Sun, but might possibly be independent of sunspots. He finally concluded that the climate variations are the first symptom of a long period variation in the Sun, which probably will be discovered later.

In the light of the present communication Professor Brückner's conclusions are of great interest, because not only does the length of

* 'Geographische Abhandlungen Wien,' Band 4, Heft 2, p. 155, 1890. "Klima-Schwankungen seit 1700 nebst Bemerkungen über die Klimaschwankungen der Diluvialzeit."

† 'Klimaschwankungen,' Brückner, p. 242.

the period, but the critical epochs of his cycle, completely harmonise with those found in the present discussion of the sunspot and magnetic curves.

To illustrate more fully this connection, and to take only one case, namely, rainfall, the three rainfall curves* are reproduced in fig. 2 (curves E, F, G).

E and F represent the secular variations for what Professor Brückner calls "Reguläre Gebiete I und II,"† while curve E is the mean for the whole set of observations he has employed, and represents the secular variation of rainfall over the whole earth as far as can be determined.

The comparison of these curves with those representing the sunspot and magnetic results given above them, shows that when the epoch of maximum spotted area (curve B) follows late after the preceding epoch of minimum (1843, 1878), or when the spotted area from minimum to minimum is least (curve D), the long-period rainfall curve is at its maximum or we have a wet cycle.

When on the other hand the maximum (curve B) follows soon after the preceding minimum (1867), and the spotted area for this cycle is at a maximum (curve D), the rainfall curve is at a minimum or a dry cycle is in progress.

It may also be observed that in a detailed investigation of the movements of glaciers, Professor Ed. Richter finds a cycle of thirty-five years. In his 'History of the Variations of Alpine Glaciers,'‡ he sums up his results as follows:—"Die Gletschervorstösse wiederholen sich in Perioden, deren Länge zwischen 20 und 45 Jahren schwankt, und im Mittel der drei letzten Jahrhunderte genau 35 Jahre betrug."

Further he pointed out that the variations agreed generally with Brückner's climate variations, the glacier movement being accelerated during the wet and cool periods.

Another very interesting investigation to which reference must be made is that which we owe to Mr. Charles Egeson, who published his researches§ in solar and terrestrial meteorology just a few months before the appearence of Professor Brückner's volume. Mr. Egeson not only finds a secular period of about thirty-three to thirty-four years in the occurrence of rainfall, thunderstorms, and westerly winds in the month of April for Sydney, but the epochs of maxima of the two latter harmonise well with the epochs of the thirty-five yearly period deduced in the present paper for sunspots.

Thus he finds that the yearly numbers of days of thunderstorm

* Brückner, *ibid.*, p. 171.

† Brückner, *ibid.*, p. 170.

‡ 'Zeit. d. Deuts.-Oesterr. Alpen-Vereins,' 1891, Band 12.

§ Egeson's 'Weather System of Sunspot Causality.' Sydney, 1889.

attain their maxima values in 1839 and 1873, and those of the westerly winds in April in 1837 and 1869. As the secular variations of the sunspots have their maxima in 1837·2 and 1870·8, the agreement is in close accord.

There seems little doubt that, during the interval of time covered by the present investigation, the meteorological phenomena, number of auroræ, and magnetic storms, show secular variations of a period of about thirty-five years, the epochs of which harmonise with those of the secular variation of sunspots.

As we are now approaching another maximum of sunspots which should correspond with that of 1870·8, it will be interesting to observe whether all the solar, meteorological, and magnetic phenomena of that period will be repeated.

Conclusion.

1. There is an *alternate* increase and decrease in the length of a sunspot period reckoning from minimum to minimum.

2. The epoch of maximum varies *regularly* with respect to the preceding minimum.

The amplitude of this variation about the mean position is about ± 0·8 year.

The cycle of this variation is about thirty-five years.

3. The total spotted area included between any two consecutive minima varies regularly.

The cycle of this variation is about thirty-five years.

4. There is no indication of the fifty-five-year period as suggested by Dr. Wolf.

5. The climate variations indicated by Professor Brückner are generally in accordance with the thirty-five-year period.

6. The frequency of auroræ and magnetic storms since 1833 show indications of a secular period of thirty-five years.

"Further Observations on Nova Persei. No. 3." By Sir NORMAN LOCKYER, K.C.B., F.R.S. Received May 17,—Read June 20, 1901.

In the last paper* I gave an account of the observations of the Nova made at Kensington between March 5 and March 25 inclusive. The observations are now brought up to midnight of May 7. Between March 25 and the latter date, estimates of the magnitude of the Nova have been made on thirty-three evenings, visual observations of the spectrum on twenty-five evenings, and photographs of the spectrum on six evenings.

The 10-inch refractor with a McClean spectroscope has generally been used for eye observations. The 6-inch prismatic camera has not been available for photographing the spectrum owing to the faintness of the Nova, but photographs have been secured by Dr. Lockyer with the 30-inch reflector on the nights of March 27, April 1 and 12, and by Mr. Fowler on March 26 and April 4. With the 9-inch prismatic reflector the spectrum was photographed by Mr. Hodgson on March 30, April 1 and 4.

Change of Brightness.

Since March 25 the magnitude of the Nova has been undergoing further periodic variations, and although observations have not been made on every night since that date, owing to unfavourable weather, yet sufficient data have been gathered to enable a general idea of the light changes to be obtained, and the few gaps can be filled up later by other observers who experienced clearer skies on these occasions.

The following table is a continuation of the observations for magnitude. Columns (1), (2), and (3) denote the observations made by Dr. Lockyer, Mr. Fowler, and Mr. Butler respectively, and Column (4) includes other estimates made by Mr. Baxandall and Mr. Shaw. The numbers in brackets represent the Greenwich mean time at which the observations (against which they are printed) were made, and refer to the evening hours (P.M.), except where otherwise stated.

Magnitudes of Nova Persei.

	(1)	(2)	(3)	(4)
March 26	4·2 (10.30)	4·2 (10.30)	—	—
" 27	3·9	4·2	—	4·2 F.E.B.
" 28	—	5·3	5·3	<5·0 H.S.
" 30	—	—	4·2	4·2 H.S.
" 31	4·3	4·3	—	—
April 1	4·4	—	4·4	—
" 4	4·3 (7.0)	4·4	4·5	—

* Page 230 [37], *suprà.*

Magnitudes of Nova Persei—*continued.*

	(1)	(2)	(3)	(4)
April 5	4·8 (10.0)	4·5	—	—
„ 6	5·5 (8.30)	—	—	—
„ 7	6·0 (7.30)	5·5	—	—
„ 8	4·2 (11.0)	—	—	—
„ 9	4·7 (11.30)	4·5	5·0	4·8 F.E.B.
„ 10	5·7 (8.45)	—	5·5	—
„ 11	5·8	—	5·6 or 7	—
„ 12	5·2 (8.45) 4·9 (9.40)	—	5·3	5·0 F.E.B.
„ 13	4·6 (11.30)	—	4·3 (8.0)	—
„ 14	5·4 (9.30)	—	5·5	—
„ 15	6·0 or fainter (8.0) 5·8 or 9 (10.30)	—	6·0	—
„ 16	5·5 (11.0)	—	—	—
„ 17	5·2 (8.30)	—	5·1 (8.30)	—
„ 18	4·2 (9.0)	4·2	4·2	4·3 H.S.
„ 19	5·2 (8.0)	—	—	—
„ 20	5·9 or 6·0 (8.30)	<5·5 (8.25)	5·6 (8.30)	—
„ 21	6·1 (9.0)	—	6·0 or 1 (9.0)	—
„ 22	5·7 (9.0)	—	—	—
„ 24	<5·5 (8.30)	—	—	—
„ 25	5·7 or 8 (8.15)	5·7	5·6 (9.0)	—
„ 26	5·6 (9.0)	5·5 (9.0)	5·5 (9.0)	—
„ 27	4·4 (9.15)	—	4·5 (8.0)	4·4 H.S.
„ 30	<5·6 (9.15)	5·8 (9.40)	—	—
May 3	5·7 (9.0)	—	—	—
„ 4	6·0 (2.15 A.M.)	5·8	5 8	--
„ 5	—	—	5·6	—

It is interesting to note that the length of the period of variability, reckoning from maximum to maximum, began after March 27 to increase from *three* days to *four* days.

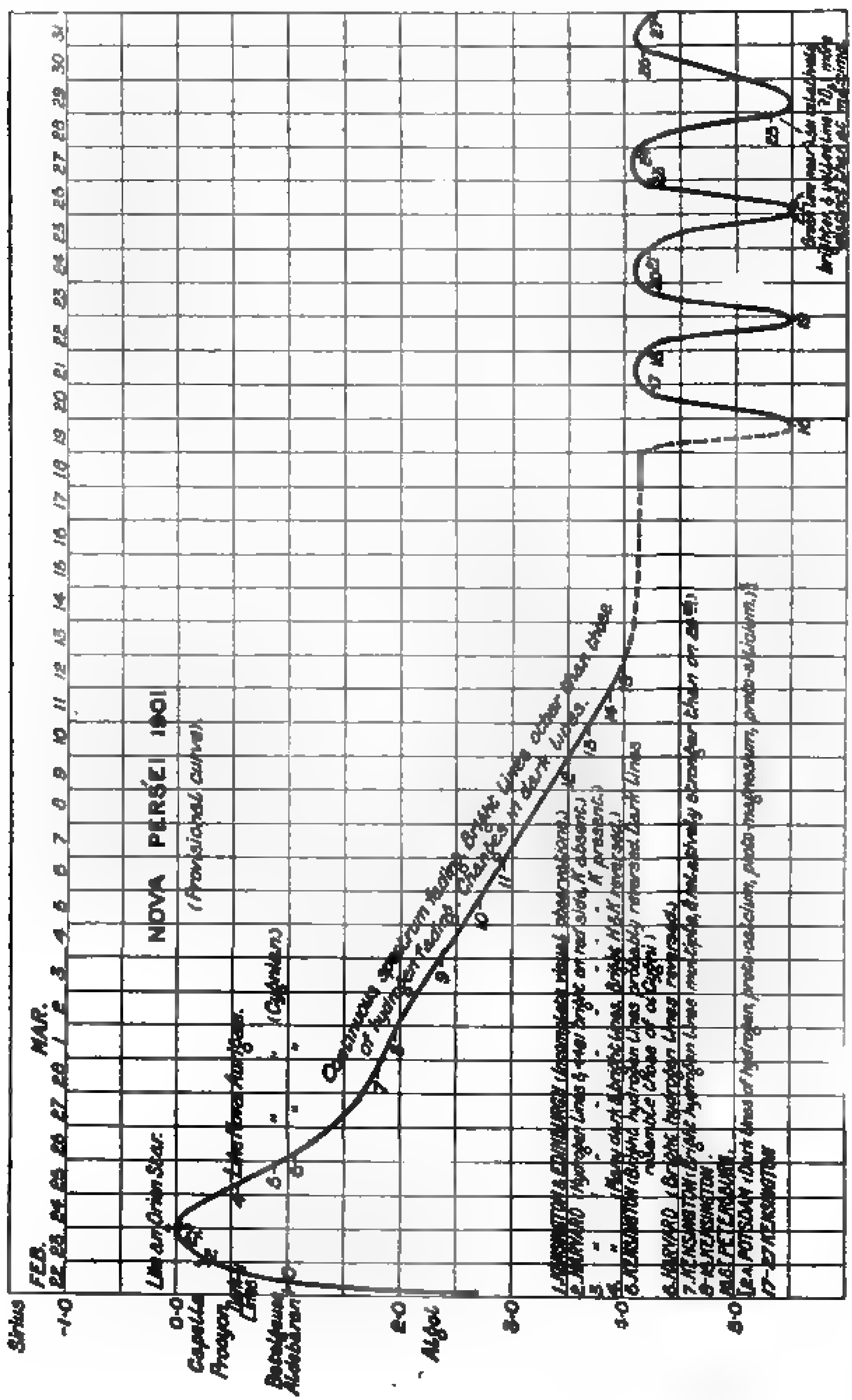
The two following maxima, after that of April 8, occurred on the 13th and 18th, so that the period became still more lengthened, namely, to about *five* days. Further observations up to May 5 seem to indicate that the five-day period is shortening.

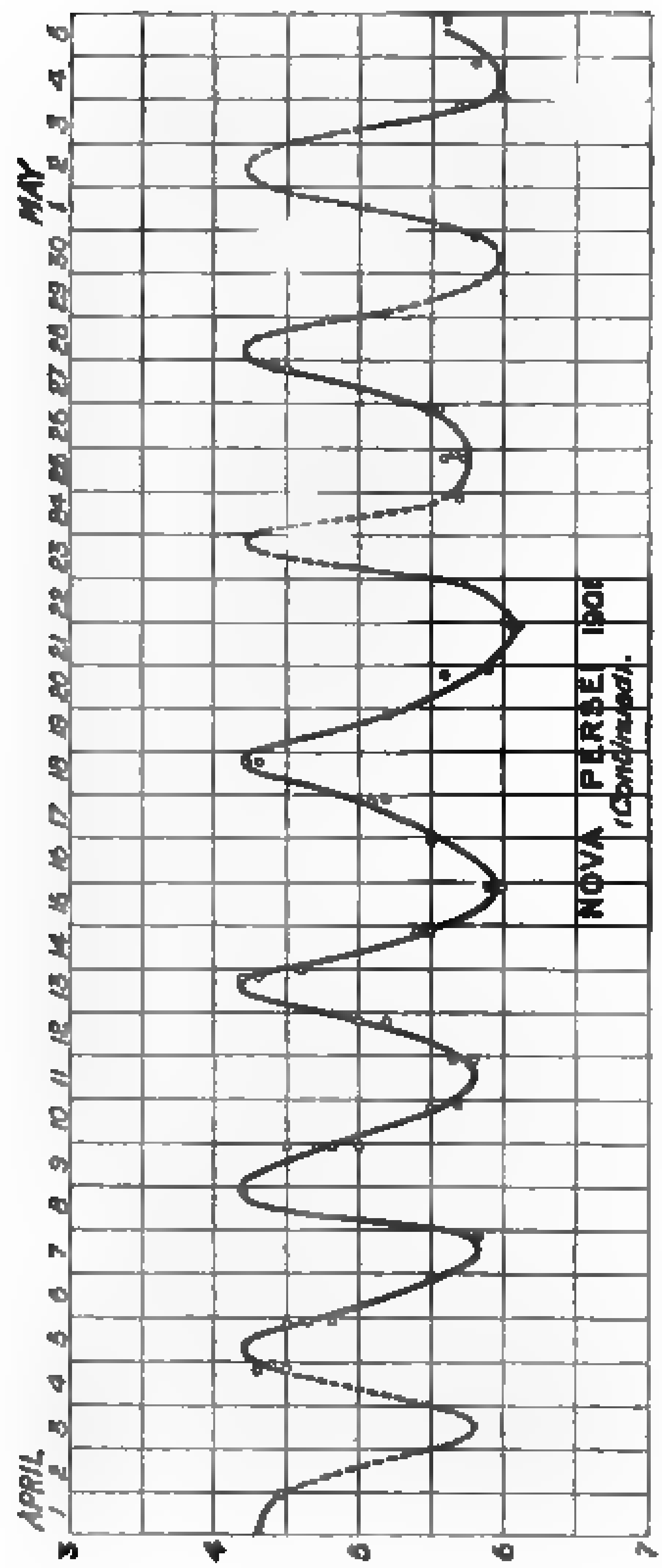
Another interesting observed fact was that the light of the Nova at the minimum on the 25th was more intense than at the preceding minimum on the 21st, the estimated difference of magnitude at these times being about 4-tenths of a magnitude. Unfortunately the increasing twilight and the unfavourable position of the Nova make it very difficult now to determine the magnitudes correctly.

The two plates accompanying this paper illustrate graphically the various fluctuations of the light of the Nova from February 22, when it had not quite attained its maximum brilliancy, to May 5.

The curve is drawn to satisfy as far as possible all the observations made at Kensington. The dotted portions represent the possible light-curve for those times when no estimates for magnitude could be secured.

In the plates the abscissæ represent the time element and the ordinates that of magnitude.


NOVA PERSEI 1901
(Provisional curve)



Colour.

In the first part of the period covered by the later observations, the colour of the Nova has been generally described as yellowish-red, red with a yellow tinge, and yellow with a reddish tinge. Since April 25 the colour has been perhaps more red than formerly, and sometimes noted as very red.

It is interesting to remark that the colour varies periodically with the change in magnitude. At maximum it is of a distinct yellowish-red hue, but at or near minimum the yellowish tinge disappears and the Nova appears very red.

The Visual Spectrum.

In the continued observations the C and F lines of hydrogen have always been recorded as "conspicuous," other prominent lines being near λ 447, λ 465, and λ 501 (the last named being sometimes as bright as F or even brighter), and a line in the yellow which recent measures show to be D_3.

The strong lines in the green at $\lambda\lambda$ 4924, 5019, 5169, and 5317, which occurred in the earlier photographs, and which were ascribed to iron, are either absent from the later photographs or appear only as very weak lines.

It has been noted that the lines 447, 501, and D_3 appear to vary with the magnitude of the star, becoming relatively more prominent towards a minimum.

The continuous spectrum has been described throughout as "weak" or "very weak."

On the evening of April 25, Messrs. Fowler and Butler made comparisons of the Nova spectrum with the spectra of hydrogen, helium, and that furnished by an air spark between poles of iron and zinc. For this purpose a Hilger two-prism star spectroscope was used with the 10-inch refractor. The hydrogen line F and the helium line D_3 were found to be sensibly coincident with Nova lines. The middle of the strong green line, previously mentioned as λ 501, practically coincided with the nitrogen line 5005·7, and therefore there is little doubt that it is identical with the chief nebular line λ 5007·6. This line was also compared with the asterium line at λ 5015·7, but was found to be decidedly non-coincident with it, though of sufficient breadth to nearly reach it.

Photographic Spectrum.

In so far as the number and positions of the lines are concerned, the few photographs available for discussion were obtained in the early part of the period dealt with in the present paper (March 26 to May 7), and show a spectrum very similar to that of March 25, which was described in detail in the last paper. The chief lines shown in the photographs are $H\beta$, $H\gamma$, $H\delta$, $H\epsilon$, and $H\xi$, together with 4471 and 4650.

Characteristics of $H\beta$.

In continuation of the series of light curves of $H\beta$ reproduced in the last paper, I give those plotted by Mr. Baxandall from the later photographs.

It will be seen that the line $H\beta$ still shows two maxima of intensity. As recorded in the previous paper, the less refrangible component gave

LIGHT CURVE OF H_β
(30-inch reflector).

indications of becoming brighter than the more refrangible member. These further photographs indicate that by April 4 the less refrangible had become twice as intense.

HARRISON AND SONS, Printers in Ordinary to His Majesty, St. Martin's Lane.

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With indication of the original pagination.

No. 4.

CONTENTS.

"The Spectrum of η Argus." By Sir DAVID GILL, K.C.B., LLD., F.R.S., H.M. Astronomer at the Cape. Received May 24,—Read June 6, 1901.

[PLATE 2.]

The star η Argus, as is well known, was for a short time almost the brightest star in the heavens. Between 1677 and 1870 its light fluctuated between magnitude 0 and 6·8, and, since the latter date has gradually faded from $6\frac{3}{4}$ to $7\frac{3}{4}$—its magnitude at the present day.

Soon after the McClean telescope was mounted, and by way of testing its performance, a plate was taken, with the object-glass prism of $8\frac{1}{4}°$ refracting angle in front of the object glass, of the area of the sky surrounding η Argus.

As this plate showed that η Argus had a very remarkable bright-line spectrum, an attempt was made to obtain a spectrograph with the slit spectroscope, together with a comparison spectrum. Within the past few weeks I have been engaged in measuring some of these experimental spectrograms—a work that other occupations had until now prevented me from undertaking.

As the reductions of the measures show that the spectrum of η Argus closely resembles that of the Nova Aurigæ, it seems to be of considerable interest, in view of the appearance of Anderson's new star in Perseus, to publish the present results, although in many respects they are not so complete as might otherwise be desirable. Thus I have no doubt that, by sacrificing the definition near $H\gamma$ and by a longer focal setting and longer exposure, one could get a considerable extension of the spectrum in both directions with the objective prism, and, with the slit-spectroscope, obtain a good determination of the velocity of the star in the line of sight by a much shorter exposure and with direct comparison of the brightest star-line with $H\beta$. These further points may, however, remain for future investigation.

The plate taken with the slit spectroscope is shown in fig. 1 (Plate 2). It was exposed as follows:—

1899.	April 14	Exposure	165 minutes.
	„ 15	„	10 „
	„ 16	„	150 „
	„ 17	„	45 „
	Total..................		6 h. 10 m.

The comparison spectrum of iron was obtained from a single brilliant spark between iron terminals connected with a powerful coil and battery of Leyden jars immediately before the first day's exposure.

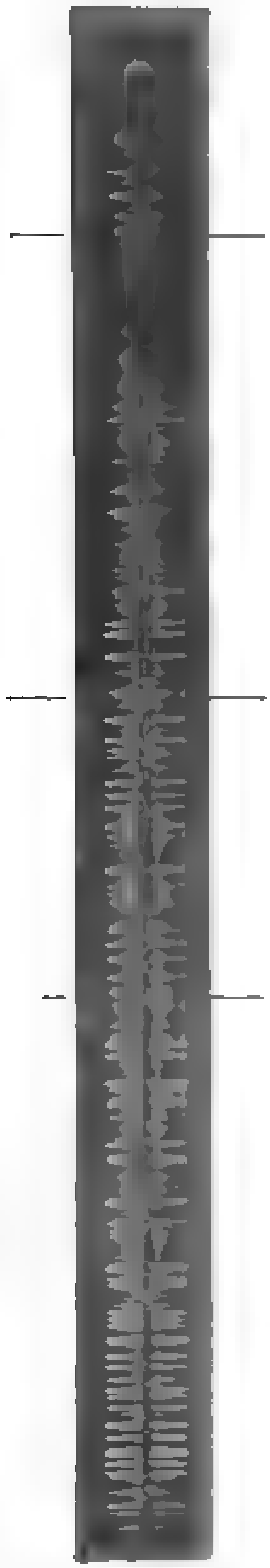

Fig. 1.

Hβ

Hγ

Hδ

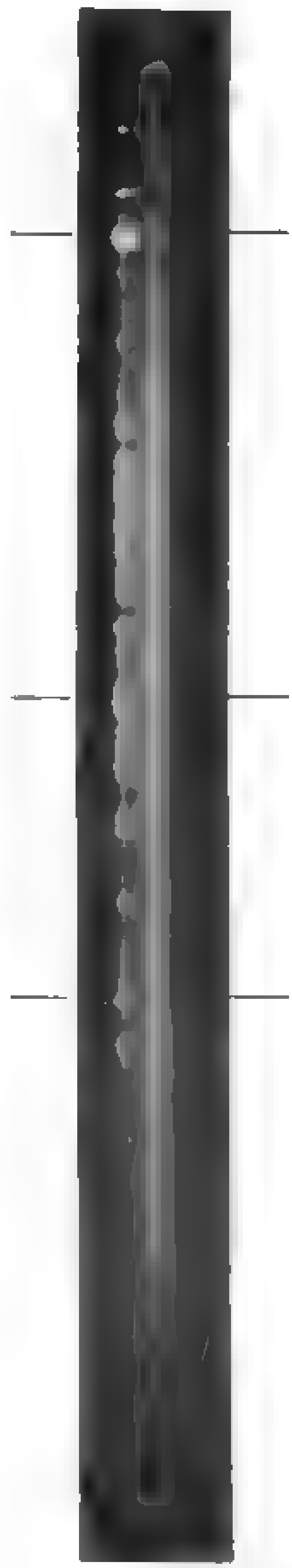

Fig. 2.

UNIV

Eleven selected iron lines were carefully measured with the Toepfer micrometer. A least-square solution with Hartmann's formula gave

$$\lambda = \underset{(\lambda_0)}{2180{\cdot}30} - \frac{\overset{(C)}{181854{\cdot}2}}{n - \underset{(n_0)}{128{\cdot}8971}}$$

of which the residuals respectively were

λ.	Resid.	λ.	Resid.
4063·72......	−0·03	4404·79.. ...	−0·15
4171·82......	−0·02	4476·34......	0·15
4118·90......	0·18	4529·1	0·30
4143·85......	−0·16	4872·25......	0·35
4260·61......	−0·06	4957·50......	−0·18
4325·88......	−0·10		

In determining the wave-lengths of the lines in the spectrum of η Argus the above formula was not used, as the representation did not seem sufficiently exact nor could the whole spectrum be conveniently measured at once.

The attached table shows the subdivisions of observation and computation. The above value of λ_0 was retained in the computations, but n_0 and C were determined separately for each block. The means of the micrometer readings are corrected for the carefully determined errors of the screw.

It will be noted that we get for the wave-lengths of the hydrogen lines the following results:—

	Observed.	Known.	K − O.
H_β	4863·38	4861·49	−1·89
H_γ	4343·71	4340·66	−3·05
H	4105·08	4101·85	−3·23

As there is no symmetry between the time of exposure of the plate to the iron flash and to the star-spectrum, we cannot suppose this displacement to be necessarily due to motion of the star; it is more probably due to change of temperature, &c., in the spectroscope. The wave-lengths given in the separate column are corrected for displacement so as to bring out the wave-lengths of the hydrogen and other lines at their true values.

The wave-lengths of the corresponding bright lines in the spectrum of Nova Aurigæ as observed at the Lick Observatory or Potsdam,* are given in the adjoining column, and the agreement is very remarkable.

The photograph with the object-glass prism was taken in 1899, January 14, with an exposure of one hour. The star was trailed to and fro for 0·5 mm., the guiding being done by a neighbouring star viewed in the guiding telescope. The original negative is enlarged 5 diameters in the plate sent (fig. 2, Plate 2).

* Scheiner's (Frost) 'Astronomical Spectroscopy,' p. 287.

The wave-lengths given in the object-glass prism table were derived from careful measures which were converted into wave-lengths by Hartmann's formula and the known wave-length of the hydrogen lines.

The wave-lengths resulting from the object-glass prism are naturally far less reliable than those from the slit spectroscope.

From the very exact agreement between the spectrum of η Argus and that of the Nova Aurigæ, it appears that whatever the causes of the origin of the Nova in Auriga, very similar causes have probably produced the historical changes in the brightness of η Argus.

Table.

Spectrum of η Argus. Measures from slit spectrograph.						Corresponding bright lines in spectrum of Nova Aurigæ.	η Argus (objective prism).	
Comparison. Micrometer. R.	Spectrum. Fe.	Spectrum of η Argus. Micrometer.	Spectrum of η Argus. λ	Spectrum of η Argus. Int.	λ Corected for displacement.	P = Potsdam. L = Lick. λ	λ	Int.
63·4193	4957·68	...	...	...	...	...	5018·2	2
		62·6624	4925·9	6	4924·2	P 4923	4924·5	4
		61·1187	4863·38 Hβ	40	4861·49	P 4862 Hβ	4861·49	40
		59·8889	4815·6	2	4813·5	...	4811·6	1
54·6904	4630·90	57·5872	4730·5	2	4828·2	...	4727·0	3 br.
54·6896	4630·90	...	...	...	...	...	4665·8	3 v. br.
54·4117	4622·00	54·6871	4630·9	4	4628·5	P 4628	4627·6	8
		54·4070	4621·7	2	4619·3	...	—	—
		53·2965	4585·9	7	4583·4	P 4583	4583·4	7
		52·8596	4572·1	3	4569·6	L 4570	—	—
		52·4900	4560·5	6	4558·0	P 4557	—	—
		52·2008	4551·5	7	4549·0	L 4549	4552·2	—
		51·6428	4534·4	4	4531·8	P 4530	—	—
		51·2971	4523·9	5	4521·3	P 4520	4518·8	v. v. b.
		51·0199	4515·6	2	4513·0	—	—	—
		50·7851	4508·6	2	4506·0	—	—	—
		50·5527	4501·7	1	4499·1	—	—	—
		50·2154	4491·7	4	4489·1	L 4490	4487·7	5 v. br.
		49·6058	4474·0	1	4471·3	$\frac{L+P}{2}$ 4472	4472·4	—
		49·4519	4469·5	1	4466·8	—	—	—
		49·1225	4460·1	2	4457·4	—	—	—
		48·9977	4456·5	2	4453·9	—	—	—
		48·7287	4448·9	2	4446·2	P 4445	—	—
		48·5516	4444·0	2	4441·3	—	4441·6	—
47·5260	4415·33	47·5599	4416·3	10	4413·6	P 4417 ?	4414·0	—
47·1436	4404·94	...	...	...	...	...	...	10
47·1424	4404·94	...	...	...	...	...	4395·8	3
46·3547	4383·72	45·4700	4360·7	9	4357·5	..	4360·3	1
44·1345	4325·98	45·1883	4353·3	6	4350·2	L 4355	4354·5	20
43·4232	4308·02	44·8215	4343·71 Hγ	10	4340·66	L 4340 Hγ	4340·66	20
43·1062	4299·44	...	...	...	...	...	4300·9	4
42·9005	4294·32	42·6890	4289·1	9	4286·1	...	4286·0	10
42·4178	4282·54	42·2246	4277·7	3	4274·7	...	4275·3	3
41·9777	4271·68	—	—	—	—	—	—	—
41·5002	4260·67	—	—	—	—	—	—	—
41·0769	4250·65	40·8929	4245·8	7	4242·7	...	4242·4	7
40·0791	4227·65	40·4445	4235·3	5	4232·2	...	4232·2	7
39·7487	4219·52	—	—	—	—	—	—	—
36·3117	4144·01	...	...	...	...	P 4176	4174·8	6 br.
35·1127	4118·72	...	...	...	...	L 4166 P 4158	4164·4	—
32·7827	4071·84	34·5930	4108·9	Suspected	4105·0	—	—	—
32·3631	4063·75	34·4388	410[illegible]·08 Hδ	3.	4101·85	L & P Hδ	4101·85	8
—	—	—	—	—	—	—	4067·0	1

br. = broad; v. br. = very broad.

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